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EXCHANGE ECONOMIES AND LOSS EXPOSURE: EXPERIMENTS EXPLORING PROSPECT THEORY AND COMPETITIVE EQUILIBRIA IN MARKET ENVIRONMENTS

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ABSTRACT

A natural economic interpretation of Prospect Theory is that people have preferences that are risk seeking in losses and risk averse in gains. Thus, according to this interpretation of the theory, individuals in an exchange economy facing only losses in wealth, would have concave preferences as opposed to the usual convex preferences. That is, if individuals could engage in trade that would reduce the magnitude of expected losses and change the variance associated with losses, they would have a tendency to seek higher variance and perhaps be willing to do so at the cost of a reduction of expected value of wealth. Such individuals would be willing to sell insurance at prices below the expected value. With concave preferences all competitive equilibria have allocations at the boundaries of the Edgeworth Box. Experimental markets were constructed to determine if such behavior could be observed. The results are that risk seeking behavior is observed in many people. Furthermore, the propensity toward risk seeking in markets is consistent with answers given to questionnaires involving hypothetical choices among lotteries. The propensity toward risk seeking appears to be reduced with experience. In one sense the data are strongly supportive of Prospect Theory but in another sense the data are not. The evidence suggests that preferences in the market setting are not labile and that the risk seeking propensities are not a result of delicate framing effects. The preferences revealed in the market seemed to be a property of the people and not simply a property of their decision processes as required by Prospect Theory.

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1. INTRODUCTION

Recent years have found attempts to integrate ideas from a psychology research tradition with ideas from economics. The integration is difficult because the purposes of the two scientific enterprises differ and the methodologies differ. Nevertheless, the lessons from one approach can sometimes find applications in the other. This paper is an attempt to accomplish such an intellectual arbitrage by merging experimental methods from economics with theory suggested by psychology.

The central focus of the experiments reported below is a psychological theory, called prospect theory (Kahneman and Tversky, 1979), which has received substantial attention in the decision literature (Camerer, 1995). The substance of prospect theory is the process of individual decision making as opposed to a substance of market activity and price formation typical of economics. For the most part economists have not been interested in the process of individual decisions. Instead, economics has proceeded on the assumption that the consequences of the individual decision making process, whatever they might be, will become manifest in the form of an individual preference relation. Thus, individual choices will be reflections of the attitudes that are summarized by the concept of a preference.

The individual in economics is captured by a preference relation over states of the world. By contrast the individual in psychology is a complex of processes that might be subject to any number of influences that are sometimes summarized by a concept of framing. Consistency such as transitivity does not follow from psychological theory. Individuals can order things if asked to do so, but the ordering is labile and may bear no relationship to choices. In fact, it is not even clear if the concept of a preference is relevant from the point of view of prospect theory. Tversky, Sattath and Slovic (1988, p.383) put the issue well, "If different elicitation procedures produce different orderings of options, how can preferences and values be defined? And in what sense do they exist?" In summary, the substance of research from psychology is that preferences are labile (Kahneman and Tversky, 1986; Kahneman and Tversky, 1981) because the process used by individuals to make decisions is subject to subtle framing effects. Thus while the processes used by individuals may be stable the existence of a summarizing characteristic of an individual such as a relatively stable or unchanging (non labile) preference is denied.

The apparent differences between the psychological view of the individual and the economic view of the individual seem to emerge from three sources. First, prospect theory is about a process of decision and not necessarily about a preference that exists as some stable or constant property of an individual. The principles of the psychological model address the nature of the steps that occur when a process of decision is invoked. Secondly, the theory addresses one time decisions as opposed to repeated decisions or perhaps even "substantially considered" decisions that might take place in markets. Third, the sources of data are questionnaires and interviews as opposed to the market choices that are typical of data in economics. Furthermore the purpose of the questionnaires is not to measure some property of an individual (such as the slope of an indifference curve) as would be the case in economics; the purpose is to demonstrate properties of a decision making process that might produce substantially different decisions under slightly altered conditions. Thus, a tension between the two disciplines can easily result from a lack of realization that they are focused on different aspects of behavior and different sources of data.

The purpose of the research reported here is to ask if prospect theory and the methods used to support it, can be employed to produce a model that captures data in a purely economic context. The research cannot be viewed as a test of prospect theory as developed by psychologists because it is being applied to a context and in a manner that differs substantially from what the originators of the theory intended. The differences are so dramatic that it might be more appropriate to refer to the theory that is to be applied here as "extended prospect theory" rather than prospect theory in order to emphasize that the liberties taken with the theory reside entirely with the present authors and not with the psychologists that are proponents of the theory.[1] The "extended prospect theory" is a theory of preferences as opposed to prospect theory, which is a theory of decision making process.

Exchange economies were created in which only losses can occur. If the principles of prospect theory are assumed to dictate properties of a stable individual preference as opposed to a property of the process used to make decisions, then the (extended and modified) theory has definite consequences for what should be observed. More precisely, prospect theory implies concavity of indifference curves in the loss domain as opposed to the usual convexity assumption of economics. With the usual convexity assumptions violated the competitive equilibria in an exchange economy have distinct properties if the equilibria exist. The research reported here inquires whether or not those properties are observed.

The second section of the paper outlines relevant aspects of ("extended") prospect theory and the questions to be posed by the research. The third section of the paper contains the details of the experimental environments. The forth section contains a specification of the models that are

[1]Several involved email conversations serve to emphasize that the psychologists claim that the theory as they use it makes no clear predications under the conditions of the experiments reported in this paper. (1)The incentives are such that subjects participate to earn money so all lotteries would be viewed as gains and no asymmetries in behavior should be observed. (2) Prospect theory is a theory of choice and not a theory of exchange. Exchange involves a procedural invariance that is not part of prospect theory. (3) The exchange environment is complex and with each trade a difference reference point can be established. Prospect theory has yet to deal with the problem of multiple reference points.

needed to produce predictions about market behavior. The fifth section contains the results. The sixth section of the paper contains the results of some special experiments that were conducted to check the theoritical coherence (or robustness) of the results reported in the body of the text. These experiments help eliminate some obvious alternative hypotheses that might be used to explain the pattern of observed results. The final section summarizes and concludes the paper. An appendix contains the instructions used in the experiments.

2. RESEARCH QUESTIONS

A fundamental difference exists between prospect theory and the traditional expected utility hypothesis as it is applied in economic context. The expected utility hypothesis rests on the proposition that choices are made as if there exists a preference relation over lotteries over final states. It is as if the final outcome is the source of value and choices reflect a process of optimization modulated by attitudes toward risk. By contrast, prospect theory does not proceed on the presumption that a preference exists for final states. Individual decisions reflect optimization based on values but these values rest upon changes of states from some reference point, which for purposes of discussion, could be viewed as a status quo. Furthermore, the value function is postulated to have a very distinct shape.

Briefly put, prospect theory rests on four axioms.
(i) Decision utilities. Decisions reflect a maximization based upon decision utilities.
(ii) Reference dependence. The carriers of decision utilities are changes in states (prospects) as opposed to outcomes or final states. These changes are relative to some outcome called the reference point.
(iii) Loss aversion. The decision utility function is steeper in the losses than in the gains. That is, the negative of a given movement in the loss direction from the reference point outweighs a positive of an equal movement in the gain direction.
(iv) Diminishing sensitivity. The decision utility function is convex in the loss domain and concave in the gain domain.

The theory has not been systematically applied to market environments but it has been the foundation for an alternative to the expected utility hypothesis as a descriptive theory of decisions. By implication, since the expected utility hypothesis is routinely used in economics, the theory might serve as an alternative foundation for market models. Exactly how one might apply the theory is not clear since the concept of a reference point in a rapidly moving market situation is itself not clear and to date there is no substantial evidence that prospect theory, as articulated by psychologists, is applicable to markets. However, some claims have been reported in the literature (Kahneman and Tversky, 1986; Kahneman and Tversky, 1991; Kahneman, Knetsch and Thaler 1990) that traces of phenomena predicted by the theory, have been detected.

The approach taken in this research is to create a market in which only "losses" can be realized and to study the resulting market behavior. Subjects were paid a flat amount of money ($60) in cash before the experiment began, which they kept during the course of the experiment. Once in the experiment they could only lose. Literally, they paid money to the experimenter. The amount of loss depended upon the decision they made to buy and to sell lotteries, which were the functional equivalent of insurance.

Each individual was given an initial endowment of units of lottery (insurance) which could be sold for cash. Or, if the individual wished (s)he could use cash to buy units of lottery(insurance) from other individuals. The setting was that of an exchange economy to which a standard competitive model might be applied. If individuals were risk averse then the indifference curves would take the usual convex properties and the competitive equilibria would necessarily be of one class. If individuals were risk seeking then the indifference curves would take a concave property and the competitive equilibria would have a boundary property of a different class. Intuitively speaking, if the indifference curves of the Edgeworth Box are convex then the competitive equilibria tend to have an interior property and if the indifference curves are concave then the competitive equilibria tend to take a boundary property. The following sections of the paper make these properties precise.

A day or two prior to the experiment, subjects were given a classroom questionnaire to complete. This questionnaire contained choices between lotteries similar to those that were used in Kahneman and Tversky (1979) to demonstrate a risk seeking propensity in the loss domain. Thus, a measurement similar to the ones used by psychologists was taken. The purpose was to compare behavior as revealed in the questionnaire with behavior revealed in the markets.

The following four general questions are posed for research.
(1) Is there any consistent equilibration behavior observed within and across experimental markets? Unlike many previous market studies, the preferences explored in the experiments reported here have not been induced. If the reference point changes depending upon the context of the decision then preferences might exhibit labile properties and as a result the markets might be erratic.

(2) Can market adjustments be associated with the equilibrium predications of the competitive model? As will be discussed later, the competitive model contains reasonably precise predictions about market behavior. However, there are very few studies in which the underlying parameters might not be convex. How the markets might behave under such circumstances is a question of general interest.

(3) If patterns of equilibration are observed do they imply the existence of risk averse people , do they imply the existence of risk seeking people or do they imply the existence of both? The standard model typically assumes that people will be risk averse while a reasonable application of prospect theory would produce people that are risk seeking. Is risk seeking in the losses a property of individual preferences? Such a discovery would be of special interest because subjects in market experiments are generally observed exhibiting risk avoiding behavior (sealed bid experiments and speculation experiments are typical).

(4) Is there any relationship between answers to the questionnaires and the behavior exhibited in the markets? Do the questionnaires produce measurements that predict behavior in the context of operating markets? Do questionnaires capture a property of an individual as opposed to a process

of decision? Psychologists typically do not view the questionnaire as measuring a property of an individual and instead view it as a demonstration of the operation of certain aspects of a decision process. Economists are typically skeptical of any methodology in which questionnaires are used, so the question is of relevance along at least two dimensions.

3. EXPERIMENTAL ENVIRONMENT, DESIGN AND PROCEDURES

A total of ten experiments were conducted. The first nine of them (as summarized in Table 1) were held under identical economic and incentive environments. Experiments are indexed by the date of the experiment. The tenth one was a "control" experiment. Its purpose and design will be discussed in the "Results" section of the paper. Until then we discuss only first nine experiments. Each experiment involved six to ten subjects. Subjects for some experiments were recruited from the California Institute of Technology and the experiments were conducted at the Caltech Laboratory for Experimental Economics and Political Science. Other subjects were recruited from classes at the University of Southern California and the experiments were conducted at the USC Experimental Economics Laboratory.

Subjects participated in one or two identical experiments. In all but 0324 and 0509 experiments the subjects were first-time participants. We call them "inexperienced subjects" (see Table 1). All of the subjects who were used in 0324 and 0509 experiments were second-time participants ("experienced subjects") recruited from subject pools of one of the previous experiments with the first-time participants. None of the subjects had experience in experiments prior to the experiments reported here.

The economic and incentive environment was as follows. Subjects were given \$60 cash before the beginning of the experiment (they were handed the money in cash).[2] They were told that the money was theirs but as a result of the experiment they could lose some of it. They were told that the amount of the loss would depend upon the decisions they would make during the market and on the outcome of a roll of dice. The word "loss" was used in the instructions in much the same way as it is used in these paragraphs.

In the economic environment there were two goods that could be traded. Each subject was told that (s)he faced two possible losses: Loss A and Loss B. That is, Total loss = Loss A + Loss B. Each individual was given an initial endowment of variable M and X. The initial endowment of M was $m^0 = 1000$ and the initial endowment of X was $x^0 = 20$ units. For trading purposes M could be viewed as cash on hand and X was units of inventory. The final loss exposure for a period of trading was

$$\text{Loss A} = < \$20 - (1/100)\, m > \quad \text{and}$$
$$\text{Loss B} = <0 \ \{\text{Prob } 1/2\} \text{ or } \$40 - x \ \{\text{Prob } 1/2\}>$$

[2] The instructions say "For your agreement to participate you will be paid \$60.00." This was handed to them in cash. Then subjects were informed that participation involved the possibility of losing a portion of their money. The experiment was designed in such a way that no one could lose more than the \$60 that they had in their hand. No one could sell more than the inventory they had and no one could spend more than the cash on hand that they were allocated. The parameters chosen guarantee limitation on possible losses.

where m is the amount of M held at the end of a period and x is the amount of X held at the end of the period.

As can be seen the variable M is literally money embedded in a loss framework and the variable X is a quantity of insurance. The expected value of Loss B offset from a one unit increase in X is $0.50. Since the value of one unit of M is $0.01 the tradeoff that leaves total expected loss unchanged is 50 units of M for one unit of X. That is, the risk neutral price of X should be $0.50.

Subjects were trained to participate in a multiple unit double auction (MUDA) as implemented through a computerized market. Standard training procedures were followed. The variable M as defined appeared as cash on hand and X was inventory.

Subjects in USC participated in three (in one in Caltech) practice market periods without payoff or exposure. These were used to test and train subjects about the accounting and how the markets functioned. The practice periods were followed by real periods in which the outcomes or final holdings (m and x) represented actual loss exposures. Each period the endowments were reset to the initial levels and no carryovers were allowed. At the end of several real periods one period was chosen at random (One of the subjects rolled dice.) and the lotteries that resulted from the trading during that period were actually played (Once again a subject rolled the dice.). The losses were collected from the subjects and they were allowed to go.[3]

The instructions and accounting forms are included in the appendix. Subjects first read the instructions and then were asked to answer the questions in an exercise that in essence tested their understanding of the content of the instructions. After the first two experiments a subject selection procedure was implemented. More subjects were recruited than were necessary - typically four or five extras. The first ten subjects that correctly answered all questions were allowed to participate. All other subjects were paid $5.00 and were dismissed. This procedure was introduced to save time in the administration of the experiment and thereby have the opportunity to conduct more periods.

A questionnaire was administered to the entire classes from which subjects were later recruited. No reference to the questionnaire was made during the experiment or was it associated with the experiment in any other way.
The questionnaire itself is included as Appendix 1. The questions themselves include the relevant questions form Kahneman and Tversky (1979). As can be seen from the Appendix they are of the form
"What would you prefer to lose: $50 for sure or $100 with probability = 1/2?"
"What would you prefer to win: $200 for sure or $400 with probability = 1/2?".

[3] Under conditions of the expected utility hypothesis this compound lottery has no influence on behavior. The implications such a compound lottery for various forms of prospect theory or even extended prospect theory are only a matter of speculation at this time. The hypothesis maintained throughout the analysis in this paper is that the compound lottery does not influence the revealed preference for the lotteries at each period. Of course, as the authors of "extended prospect theory" we are free to do what seems to us to be most natural and convenient.

An individual that prefers a lottery to the expected values of the lottery is exhibiting risk seeking type of answers. The stylized fact that has emerged from the Kahneman and Tversky research is that people are risk seeking in the losses. The data in support of this stylized fact are almost exclusively answers to questionnaires.

4. MODEL

The model that will be applied to guide the analysis will be the general competitive equilibrium for an exchange economy. It is well known that this model is reasonably accurate under conditions in which preferences are induced and thus can be assumed to be known and fixed (Noussair, Plott and Riezman 1995). Furthermore, it is known that the predictions of the model are also accurate under preference conditions that produce market instability (Plott and George 1992). Thus the analysis will rest on a general assumption that regardless of the preferences that may be present in the economies, the markets will seek the competitive equilibrium as long as one exists. Of course under the conditions of the experiments reported here the preferences are not known and according to the psychology model might not be fixed or might not even exist; and, if preferences do exist in the form suggested by the model from psychology, extended prospect theory, then they will exist in a form that can cause market instability in the sense that individuals will always want to move to a boundary of an opportunity set. In this section the model will be developed under several assumptions about what preferences might be.

As will be demonstrated in this section, the patterns of equilibrium behavior under different assumptions about preferences can differ dramatically. The analysis will first focus on the case in which all individuals are either risk averse, all risk seeking or all risk neutral. The primary focus will be on the shapes of indifference curves and the implied demand curves under conditions of competition. The analysis will then address cases in which different numbers of individuals might be risk averse (RA) and risk seeking (RS) and the related problems of equilibrium.

The key distinction for theory is the axiom of risk seeking in the losses. If individuals choose to maximize expected (decision) utility and if individuals are risk seeking in the losses then individual indifference curves are concave to the origin instead of convex. In such case the individuals have an incentive to move to a corner solution of a budget set at any given set of prices. If individuals are risk averse then they might want to move to the boundary of an opportunity set under some prices but there always exist prices at which they would want to remain on the interior of the opportunity set. The consequences will be for competitive equilibria to have certain boundary cases if the agents in the experiment are risk seeking while interior equilibria can also exist if the agents are risk averse. This special property of the equilibria will form the bases for the evaluation of results.

The first proposition to be established is the relationships among assumptions about risk seeking propensities, risk aversion and the shapes of indifference curves. From the point of view of the model the individual must choose a combination of two commodities, M and X. Preferences over these two commodities reflect the fact that different combinations dictate different lotteries over monetary losses that the individual must experience. Different indifference curves for m and x (the final holdings of M and X respectively) will result from different assumptions about the characteristics of an individual's preferences over these resulting lotteries, if indeed a concept of preference is relevant to attitudes toward lotteries- recall in some interpretations of prospect theory individuals do not have preferences in the form used by economics and employed here.

The following notation is used hereafter :

M = the notation for the numeraire
m^0 = the initial endowment of M
m = the quantity of m held at the end of a period
X = the notation for the commodity
x^0 = the initial endowment of X
x = the quantity of X held at the end of a period
F'_y= the derivative of the function F(.) with respect to the variable y.

The lotteries defined by the choice of m and x are Loss A for sure and Loss B with a .5 probability. These prospects can be recombined into a choice of lotteries dictated by a choice of x and m, and are of the form:

probability .5 { loss = \$(20-m/100) }
probability .5 { loss =\$(60-m/100 - x)}

so the expected value of the loss is 40 - m/100 - .5 x.

Three general background assumptions will be used throughout.

(a) The commodity space is two dimensional as characterized by the variables M and X, which characterize exposure to lotteries of monetary losses or changes in wealth from some current value w. M takes values $0 \leq m \leq 2000$ and X takes values $0 \leq x \leq 40$.

(b) Individuals preferences over lotteries are *as if* the individuals wished to maximize the expected value of a (twice differentiable) utility function of money.

Assumptions (a) and (b) can be summarized by an assumption that the individuals act as if they wished to chose m and x to maximize

$$EU_i(w,m,x) = 0.5\, U_i(w,\ m/100 - 20) + 0.5\, U_i(\ w,\ m/100 - 20 + x - 40)$$

where w is the value of current wealth. Ordinarily the expected utility hypothesis would assume that the function was of the form $U(\ w+\Delta w)$. Here the distinction is made because of the following assumption.

(c) The relevant reference point for purposes of application of prospect theory is w. Furthermore the analysis will suppress w since it is assumed to be the same throughout the experiment.

Of course this suppression is not really consistent with psychological reasoning since the reference point is presumed to be context dependent and thus might take any form at all in such a complex environment as a market.

Indifference Curves.

The proposition to be stated below demonstrates that the indifference curves in two dimensional space, under the general assumptions above, are concave to the origin if the individual is risk seeking as suggested by prospect theory. If the individual is risk averse the indifference curves will have the usual convexity property and if the individual is risk neutral then the indifference curves will be straight lines with a well defined slope.

PROPOSITION 1. Consider a utility function satisfying the general assumptions (a), (b) and (c) above. If

1. $U'(z)>0$ for any z .
2. $U''(z)<0$ for any $z<0$ if a subject is Risk-Averse in losses.
3. $U''(z) > 0$ for any $z < 0$ if a subject is Risk-Seeking in losses.
4. $U'(z) = 1$ and $U''(z) = 0$ if a subject is Risk-Neutral

then in the MN case the indifference curves of the final holdings of M and X satisfy the following properties: (where subscripts represent partial derivatives)

1. $x'_m < 0$ for any m : $0<m<20$.
2. $x''_{mm} > 0$ (Convex) if a subject is Risk-Averse in negatives.
3. $x''_m < 0$ (Concave) if a subject is Risk-Seeking in negatives.
4. $x'_m = -0.02$ and $x''_{mm} = 0$ if a subject is Risk-Neutral.

SUPPORT. See Appendix 3.

The typical indifference curves for all types of subjects are shown in Figures 1a, 2a and 3a. For risk averse individuals the indifference curves must have the usual convex to the origin shape (Figure 1a). For risk seeking individuals the preferences are concave to the origin as shown in Figure 2a. For risk neutral individuals the curves are straight line with the designated slope of -0.02 (Figure 3a). Notice that the slopes of all curves are less than or equal to -0.02 regardless of attitudes toward risk of loss.

Excess Demand Functions

The analysis will ultimately lead to a consideration of various aspects of competitive equilibria. Useful tools to help one understand the possibilities under various conditions are the demand functions. Demand functions are solutions to the constrained optimization problem:

$$\text{MAX}_{m,x} \quad 0.5U(m/100 - 20) + 0.5U(m/100 - 20 + x - 40)$$

subject to

$$m+P\,x \leq m^0 + Px^0 \quad, 0\leq m\leq 2000,\ 0\leq x\leq 40, \text{ where } m^0=1000,\ x^0=20$$

P is the price of inventory X expressed in terms of units of M per unit of X. The initial endowments of M and X are designated by m_0 and x_0. A similar problem exists where the lottery is the numeraire except in that case prices of M are stated in terms of the number of units of X it would take to buy one unit of M. A solution to the maximization problem produces the individual demand curves.

Since the functional forms of the utility function are not specified, only the qualitative features of excess demand functions can be obtained. Some general properties of the excess demand functions will be discussed for all three cases of risk aversion, risk seeking and risk neutrality. Begin with a price of 50 in Figure 1a. It is the diagonal line from the upper left to the lower right. This price plays an important role in determination of the demand equations. Any transactions made at a price of 50 preserves the expected value of initial endowments. In other words, a risk neutral person would be indifferent between buying or selling at that price. If the trade increased variance of final money a risk averse person would not move along this price line but a risk neutral person might and a risk seeking person would.

First consider the excess demand functions of a risk averse individual and continue to study Figure 1a, which illustrates the solutions of the utility maximization problem. The demand functions derived from this exercise are of the form of the functions represented in Figure 1b. If the price P is lower than 50 then by Proposition 1, the quantity demanded above the initial endowment will be equal 20. In other words all risk averse subjects will be willing to buy 20 units of X to add to their initial endowment, which is equivalent to buying as much insurance as is possible. If the insurance cost is less than the expected value of the loss, a risk averse person will always buy. If the price is equal to 50 then the quantity demanded by a risk averse person is also equal to 20. The individual would prefer to spend the money an avoid the exposure to risk that is implicit in a fair bet. At prices that range from 50 to p** (Figure 1a) the quantity demanded falls continuously from 20 to some negative q** (Figure 1b). At the low price the risk averse person is a buyer of insurance but as the price get high the purchases fall and if the price of insurance is high enough then in spite of the risk aversion the individual will sell insurance. At prices from p** to $+\infty$ the individual has no use for the money because of the boundary on the values that m can take, and as a result the demand is goes from q** to 0 proportional to 1/P.

Figure 2a illustrates the solutions to the utility maximization problem for a risk seeking individual and Figure 2b graphs the qualitative features of the resulting demand functions. At any price of 50 or above a risk seeking individual will always be on the sellers side of the X market. A risk seeking individual prefers the risk and variance in wealth so would always prefer to take the money and assume the risk of a "fair bet". Thus, at prices above 50 the risk averse person will always have an excess demand of -20. However, because of the constraints on the value of M their demand for X will increase from -20 to 0 proportional to 1/P as P increases.

At some prices below 50 risk seeking individual would participate as a seller of insurance. At a price slightly below 50, (s)he would prefer to take the cash and assume the risk. However there is a sufficiently low price, equal to p* (Figures 2a and 2b), at which a risk seeking person is indifferent between -20 and 20. Such a price will always exist because of the continuity of the utility function. If the price is less than p* then the risk seeking individual will demand 20 units of X. At that p* the price of insurance is so low that the risk seeking individual will buy it because the increase in expected wealth more than compensates for the fact that the variance in wealth will fall as a result of the purchase.

All risk neutral subjects will be on the buyers side of the market if the price is lower than 50 and on the sellers side if the price is higher than 50. At the price equal to 50 they are indifferent between all points that are within the interval [-20, 20]. Figure 3b presents a typical demand function of a risk neutral person.

It is important to note that with only one exception the individual excess demand functions are continuous. The only exception occurs in the case of the excess demand function of a risk seeking person, which has one point of discontinuity at a price of p*. At that price the function has two values: 20 and -20.

Competitive Equilibria.

With the properties of the individual excess demand functions established the analysis can focus on the possible properties of equilibria that can emerge from an exchange economy. Important to this determination will be the relative numbers of risk averse (A), risk seeking (S) and risk neutral (N) in "losses" individuals that happen to exist in the economy. Recall that preferences are not controlled in these experiments and that the individual brings to the market whatever preferences or attitudes that he or she has.

The problem, can be formally written within the framework of a J-person, two-goods, pure-exchange economy. Thus consider J individuals A of whom are risk averse, S are risk seeking and N are risk neutral in losses. The preferences and utilities are assumed and defined in Proposition 1.

There are two goods in the system: "francs", denoted by M and "units of inventory", denoted by X. Any individual is allowed to have $0 \leq X \leq 40$ and $0 \leq M \leq 2000$ in his possession. Extra francs or units of inventory do not increase utility. The two goods have value in the sense that an increase or either or both will decrease exposure to a monetary loss. Initial endowments are denoted as m_0 and x_0 where $m^0 = 1000$ and $x^0 = 20$. The notation of price P is determined as an amount of francs used to acquire one unit of X.

Individual excess demand functions derived under the conditions of the economy are as described in the paragraphs above. The attention now turns to equilibria. The possibility of nonconvexities makes any discussion of equilibria rather complex. In particular the existence of equilibria depends upon a relatively delicate balancing of the number of individuals with different types of preferences. The Walrasian dynamics drives the system in the consistent way but the price itself might be supported only by a delicately balanced allocation. Recall that in the case of non convex preferences there is a tendency to go to the boundaries. Since everyone wants on the boundary (and all initial endowments are equal) the number of people that want to sell must exactly equal the number of people that want to buy.

Formally, a competitive equilibrium exists in the system if and only if there is a price p^e at which total excess demand ($D(p)=\Sigma Q_i(p)$, where $Q_i(p)$ is an individual excess demand) has a value of 0, $D(p^e)=0$. Figures 1b, 2b and 3b show that the shapes of the individuals excess demand curves depend on types of the individuals. That implies that the shape of the total excess demand curve and the equilibrium price depend upon the relative numbers of risk averse, risk seeking and risk neutral individuals in the system. The following three propositions use the notion of the total excess demand to provide sufficient conditions for the existence of a competitive equilibrium and to compute equilibrium prices under different relative N, S and A. Proofs of the Propositions can be found in the Appendix 3.

PROPOSITION 3. If there are only Risk Averse subjects in the system (S=N=0) then under the conditions on the preferences and identical initial endowments a competitive equilibrium always exists at a price strictly higher than 50.

PROPOSITION 4. (S=0) If there are no Risk-Seeking subjects in the system then under the conditions on the preferences and identical initial endowments a competitive equilibrium always exists. Equilibrium price is higher than 50 if A>N and equal to 50 otherwise.

PROPOSITION 5. Under the conditions on preferences, identical initial endowments and even number of subjects a competitive equilibrium always exists. Equilibrium price is lower than or equal to 50 if $S \geq A+N$ and greater than or equal to 50 if $S \leq A+N$. Moreover, if $S > A+N$ then equilibrium price is strictly lower than 50.

The following two observations follow directly from the Propositions 3-5.

Observation A. Only individual maximum net trades should be observed if the equilibrium is at a price less than 50. That is, if the equilibrium price is lower than 50 then all individuals should trade the maximum of 20 units.

Observation B. The number of buyers should be equal to the number of sellers in the market if the equilibrium is at a price less than 50 . The market volume of net trades should be [20 (J/2)] at equilibrium prices less than 50 .

The Table 2 summarizes the major results of this section. The equilibrium price predictions of the competitive model are listed conditional on the relevant environmental assumptions.

It is important to note that the theoretical analysis proceeds on the assumption that there is always an even number of people who follow the expected utility hypothesis and either have risk avoiding, risk seeking or risk neutral preferences. If someone does not participate or if an individual has preferences that are substantially different from the ones postulated then the dynamics of the markets still could be similar to that postulated in Propositions 3-5 because of the limited influence one individual can have by virtue of the constraints on the budget set. Of course existence of equilibrium in the model is another thing and the presence of such individuals could force the system into an environment in which the equilibrium does not exist in the competitive model. If for some reason an individual wants only a few units then delicate balancing of individuals is impossible and the logic applied to generate existence in the models applied here is destroyed.

5. RESULTS

The time series of all periods of all nine experiments are shown in Figures 7-15. Shown there are the contract prices as they occurred in time. The vertical bars represent the change of periods. A large black vertical bar represents the change from the practice periods to the periods for which the consequences would result in actual losses. While the figures show all data including the practice periods, only the real payoff periods are considered in the data analysis discussed in this section. The practice session is included only for illustrative purposes. The horizontal dotted line is the reference price of 50.

The impression from the figures is that in all but one experiment transaction prices were consistently lower than 50 and that in most cases prices settled to some sort of an "asymptote". The only exception is experiment 0501. The impression is supported by the first result. The importance of the result is that according to the model , the implication of such prices is that at least half of the subjects in the experiments were risk seeking.

RESULT 1. The transaction prices tend to be no higher than the risk neutral level of 50. The estimated asymptote of such movements were lower than 50.

SUPPORT. The first claim of result relies on the data presented in the Table 3. The numbers in the Table are average transaction prices across actual payoff periods and experiments. Notice that there are only seven exceptions to the statement of the result and six of these exceptions exist only in experiment 0501, In many periods of several experiments the average prices were within one cent of the risk neutral price of 50 thereby suggesting the hypothesis that subjects were risk neutral and that subjective transaction cost would account for the difference. This possibility is discussed later in the paper. For now, it must be remembered that virtually all transactions were made below the risk-neutral level of 50 (see Figures 7-15).

For the second claim of the result, the destination and the direction of the equilibration process must be determined. The destination and the direction of the price convergence was evaluated by the application of a simple dynamic model, [Noussair, Plott, Reizman, 1995]. The model assumes that price (dependent variable) may start from a different origin for each experiment, but the convergence is assumed to be to a common asymptote in all experiments. Formally the model is as follows:

$$P_{it} = B_{11}D_1(1/t) + \ldots + B_{1K}D_K + B_2((t-1)/t) + u_{it}$$

where i is the index of the experiment, D_j are dummy variables that take value 1 if i=j and value 0 otherwise, t is time measured in terms of experimental period number, K is number of experiments, P_{it} is the average price in period t of the experiment i, u is a random variable, distributed normally with 0 mean. B_{1i} measures origin of the price convergence process and B_2 is an asymptote.

Data in Table 4 show ordinary least squares estimation of the model. The estimated asymptote was 46.11 and the risk neutral equilibrium price was at 50. Thus, the statistical model suggests that the price equilibration was to the price lower than the risk neutral level of 50.•

The next result is focused on the convergence process and the degree to which it can be described as being toward the competitive equilibrium . All experiments involved an even number of subjects so by Propositions 5 and 6 and under the general maintained hypothesis, a competitive equilibrium existed in all nine experiments. Prices and final holdings should be considered. Price patterns were considered in Result 1. The conclusions about the destination of the price movement process, combined with the patterns of competitive equilibria predicted by the model, suggest the extent to which patterns of net changes of final holdings are consistent with the view that the process was converging toward a competitive equilibrium. It is important to note that the result addresses a convergence process because none of the processes could be said to have perfectly equilibrated.

RESULT 2. Market movement toward a competitive equilibrium was observed across experiments. The
propensity for movement toward competitive equilibrium quantities is more pronounced as subjects have experience in more than one experiment.

SUPPORT. The first step of the support is to show that a tendency of price equilibration in a sense of a falling variance of price, was observed across experiments. Data in Table 5 show that the standard deviations of the prices were lower in the final periods of every experiment , compared to earlier periods, thus suggesting price equilibration.

The next step is to determine, if one of several patterns of competitive equilibria predicted by the model was observed across experiments. The competitive model predicts a pattern of prices and closely related final holdings. We know from Result 1 that prices as well as the asymptotes of the process were no higher than 50 in all but one experiment.

Observation A is that the equilibrium final holdings are at the boundaries if prices are below 50. Observation B is that in equilibrium the number of sellers should equal the number of buyers given the transaction prices are less than 50 and the observation also contains a prediction for the total volume. Observations A and B as well as Result 1 imply that in equilibrium each subject should have bought or sold 20 units of inventory, thus making final holdings equal to 40 or 0.

Data on final holding is a bit less decisive than on prices, but relevant statistics are in Table 6. Shown there are the numbers of individuals who increased or decreased their holding of X by various levels. The last two periods of an experiment were averaged for each individual and used as the measure to indicate the individual's position. The numbers of buyers are approximately equal to the numbers of sellers (40 vs 38), and we find fifty seven out of seventy eight people have moved half way (at least nine units) or more toward the boundaries. This is more than 73% of the individuals.

The fact that not all of the individuals have moved to the boundaries shows up again in the volume numbers. Data in Table 7 show the time series of net trade volumes across experiments. In five out of nine experiments the volumes were substantially lower than the predictions of the competitive model and there were no clear signs of volume convergence to the predicted quantities. The relevance of this phenomena will be discussed later in the paper where individual behavior of subjects will be considered.

The subjects who participated in two experiments tended to have higher net changes of final holdings in the second experiment in which they participated. Data in Table 8 compare average (of the last two periods) final holdings of the subjects for the USC experiments: 0316,0317,0324 and for the Caltech experiments: 0501,0502,0505,0509. The first two experiments (0316 and 0317) in the USC experiments and the first three experiments (0501, 0502, 0505) in the Caltech set involved inexperienced subjects. All of the subjects in the USC, 0324 and in Caltech, 0509 had the experience of previous participation in one of the earlier experiments. First, notice that six of the seven subjects who came close to the boundaries (bought or sold more than two-thirds of the theoretically predicted quantities) during their first experience kept that tendency for their second participation. Secondly, fifteen of twenty subjects under consideration increased the absolute values of their final holding changes the second time of participation. Thus, the evidence for movement toward a competitive equilibrium allocation is stronger in markets in which subjects were experienced.

In summary, price convergence receives substantial support but allocation results are less so. Movement toward the boundaries occurs, but in the USC experiments the movement is incomplete resulting in volumes that are less than the competitive prediction. While the evidence is thus mixed, we conclude that a tendency of convergence toward a competitive equilibrium was observed across experiments .•

The next result states the implications of the particular competitive equilibrium observed, as related to the numbers of different types of preferences. As Proposition 6 states, because prices are so low, there must be more risk seeking people in the system than risk averse and risk neutral combined. Result 3 says that there are individuals that are risk seeking in the losses, but it also makes explicit the fact that such properties of individuals can be observed in market behavior. Later it will be shown that it is possible not only say that there were risk seeking people in the system but also separate them from risk averse people.

RESULT 3. The number of risk seeking subjects in the experiments was no less then the number of risk averse and risk neural subjects combined.

SUPPORT. Proposition 6 states that only in the cases in which the number risk seeking subjects is no less than the number of non risk seeking ones ($S \geq N+A$), can the competitive equilibrium price be at some level which is strictly lower than 50. Average period prices (Table 3) as well as econometric data (Table 4) demonstrate that that was the case in the experiments. Result 2 states that the convergence was toward a competitive equilibrium. Thus, it is possible to apply Propositions 5 and 6 to the experimental data and conclude that the number of risk seeking subjects in the experiments was no lower then the number of non risk seeking ones.•

The conclusion is consistent with the diminishing sensitivity axiom of prospect theory, which predicts such a behavior in losses. However, the price equilibration across experiments, identified in the previous paragraphs, has one major implication, which is very important for the discussion of the relevance of prospect theory for economics from a methodological point of view. Namely, equilibration suggests that, contrary to prospect theory as advanced by psychologists, preferences exist and do not exhibit labile properties depending on reference point changes. This issue will be pursued toward the end of the results section.

The next result evolves from an inquiry that has two forms. First, do the questionnaires used extensively in psychological studies lead to measurements of properties of people that will be manifest in market behavior? The second form is a corollary to the first. Is risk seeking in the negatives a property of individual preferences or is it a property of the way that people think about things? Is it a property of preference or is it a property of the process of preference formation? As it turns out the questionnaires have a biased property but nevertheless provide strong predictive powers about market behavior. Thus, one cannot reject the notion that the questionnaires measured a property of preference as opposed to a feature of cognition.

The analysis will consist of three steps. First, the subjects will be classified as RA or RS according to their behavior in the experiments. Secondly, the same classification will be completed according to their answers to the questionnaires. Comparison of two classifications will provide support for the statement of results.

A classification of the subjects by their behavior in the experiments is developed by using the equilibrium patterns suggested by the model. Subjects can be classified into three different categories, according to their final holdings . Only two last periods of every experiment were used in the analysis. Data in Table 9 show the results of such a classification.

1. Risk Seeking ("RS") - This class contains subjects who satisfy the following condition:

They moved at least half way toward the "sellers" boundary on average, i.e. they sold at least ten units of X on average in the last two periods of the experiment.

2. Possibly Risk Averse ("RA") - This class contains subjects who satisfy the following condition:

They moved at least half way toward the "buyers" boundary on average, i.e. they bought at least ten units of X on average in the last two periods in the experiment.

The competitive model predicts (Propositions 5 and 6) that in equilibrium, when the prices are sufficiently lower than the risk neutral price, risk seeking people can demonstrate the same behavior as risk averse people: buying units of inventory. On the other hand, if a subject is on the sellers' side of the market and prices are below 50 then that subject is exhibiting risk-seeking behavior. Thus, formally, the numbers in Table 9 represent lower bounds of the numbers of the risk seeking people in the experiments and the upper bounds of the numbers of the risk averse subjects.

3. "?"- It is hard to say about subjects. This class contains subjects who did not demonstrate a "consistent pattern" of behavior. In other words, these were subjects who:

i. may have been moving in a direction of the boundaries, but did not demonstrate any pattern of consistency.

ii. were trading around the status quo, instead of moving toward some boundary, but showed no consistent behavior.

iii. were not buying or selling anything at all.

iv. demonstrated a mix of i, ii and iii.

Data in Table 9 demonstrate the results of the classification. Notice that approximately two thirds of all subjects (53 out of 82) were classified as RS or RA and the other third was classified as "?". Since, as discussed in the previous paragraphs, those subjects who were classified as RA could in fact be RS if prices were sufficiently low , the results of such a classification should be interpreted to be that there was no less than 50% of the people in the experiments that were risk seeking. This classification is consistent with the claim of Result 3 that risk seeking accounts for a substantial proportion of behavior.

The classification provides a possible insight about the weaknesses in the support for equilibration. Recall from the support of the Result 2 that the total net volumes of trades were lower than predicted by the competitive model. Now it becomes clear that such a phenomena is likely due to the great number of subjects who were classified as "?". The common feature of most of such subjects is that they did not move far from the status quo. In other words they all had low net volumes across periods and as a result they could not be classified as RA or RS. Data in Table 7 show that the net volumes were approximately 10-50% lower than ones predicted by the model. On the other hand one third of subjects were classified as "?", thus providing support for the claim that the "?" subjects were responsible for low net volumes.

A classification of the subjects according to their answers to the questionnaires was done. All of the subjects were asked to answer the following questions: What would you prefer to loose:

	For Sure	With probability 1/2
1	$500	$1000
2	$20	$40
3	$3000	$4000 (p=.8)
4	$7.50	$15
5	$1	$2

According to their answers they were qualified using two different types of classifications:

Type 1 classification:
Risk-Averse - 3 or more answers "for sure" ;
Risk-Seeking - 3 or more answers "with probability = 1/2"

Type 2 classification: (according to the answers to single question)
Risk-Seeking - Would prefer to loose $40 with probability = 1/2 instead of loosing $20 for sure.

Questionnaires were completed by all 82 subjects who participated in the experiments.

According to the Type 1 criteria 66(80%) were "Risk-Seeking"
16(20%) were "Risk-Averse"

According to the Type 2 criteria 61(74%) were "Risk-Seeking"
21(26%) were "Risk-Averse"

With the measurements above completed the result can now be stated. The essence of the result is that the questionnaires have predictive power about behavior in markets.

RESULT 4. There is strong consistency between answers to the questionnaires and experimental market behavior. However, the questionnaire has a substantial bias that overestimates the number of risk seeking individuals relative to the number of risk averse individuals. [The error rate of risk seeking answers in the questionnaire is greater than the error rate of risk averse answers to the questionnaire. That is, an individual responding in a risk averse manner in the questionnaire was more likely to behave that way (RA) in the experiment than was a person who was Risk-Seeking in the questionnaires.]

SUPPORT. The numbers in Table 10 represent relationships between the experimental data and the data from the questionnaires. If only subjects who were classified as RA or RS are considered then the probability that a subject who appears to be RS according to the questionnaires would demonstrate the same kind of behavior in the experiment ($p(RS_{exp}|RS_{quest})$) is equal to .65 (.63 for type 2 of classification). Similarly $p(RA_{exp}|RS_{quest})=.35$ (.37) , $p(RA_{exp}|RA_{quest})=.87$ (.80), $p(RS_{exp}|RA_{quest})=.13$(.20). Two conclusions follow about relevance of the questionnaires for predicting market behavior. First, answers to the questionnaires do produce measurements that can be used as a rough prediction of the behavior in the context of operating markets, since the probability of consistent (with the answers) behavior is .73. Secondly, the likelihood of a deviation in the experiment from the answer given to the questionnaire is two and a half times higher (35/13) for risk seeking subjects (questionnaire) rather than for risk averse ones (questionnaire). It is important to note that the results are the same for both types of classification. In other words choice of either of the two different types of classification does not change the results. Finally, the fact that the number of RA people was likely overestimated and the number of RS people was underestimated implies even stronger consistency between answers and actions than presented above. •

6. RESULTS AND THEORITICAL COHERENCE: THREE TESTS

The results as reported go beyond a simple reporting of statistics. There is an attempt to weave a sense in which the statistics are consistent with the principles that support "extended prospect theory" as integrated with the competitive model. Since the data do not perfectly fit the competitive model, as modified to include the possibility of risk seeking behavior in the negatives, there might be alternative explanations. In this section we discuss additional experiments that explore three possible alternative explanations of the data. Space limitations prevent any detailed reporting but these additional experiments can be used as some indication of the robustness of the major results reported in the body of the paper. These additional experiments will be referenced as "additional controls".

The motivation for the first additional control experiment was the fact that transaction prices in most experiments tend to be very close (a penny below) to the risk neutral level of 50. In view of such data, a possibility exists that that the subjects were risk neutral and that transaction costs accounted for the observed lack of accuracy of the model. To test this hypothesis (risk neutrality) an additional control experiment (0509) was conducted. This experiment involved a special selection of subjects from those that had participated previously. Subjects were chosen that had previously demonstrated risk seeking behavior according to the model. Aside from the selection of subjects, the experiment was an exact replica of all previous experiments. All subjects who participated in experiment 0509 had already participated in one of the previous Caltech experiments: 0501, 0502 or 0505. All but one of the subjects chosen for 0509 were those that could be classified as risk seeking as a result of their previous participation. Data in Table 3 show that in the three previous experiments (0501,0502 and 0505) prices were close to the risk neutral level of 50. Thus, if the subjects were risk neutral then the transaction prices in the experiment 0509 should be also near 50. On the other hand, if the existence of risk seeking individuals interpretation of the data is correct , then, as the model implies, the prices in experiment 0509 should be significantly below 50.

The last column in Table 3 presents transaction prices for the additional control experiment 0509. It is clear that the prices were not only below 50 but are far below (about 20%) the prices in the experiments 0501, 0502 and 0505. Thus the prices are out of the range of any previously observed transactions costs deviation from equilibrium. Since market prices were substantially below the risk neutral equilibrium, the model implies that there at least as many risk seeking subjects as there are risk averse and risk neutral combined, so the hypothesis about general risk neutrality can be rejected.

A second additional control experiment (0516) was conducted to explore the idea that the observed risk seeking behavior could be explained as a property of general risk seeking preference, as opposed to simply risk seeking in losses. If subjects change their risk seeking behavior to risk averse behavior when the experimental conditions are formulated in terms of gains as opposed to losses, then the hypothesis of general risk seeking preference can be rejected. Does the risk seeking behavior observed simply reflect the attitudes of individuals that prefer risk taking in general, or is it the case that preferences are different for gains as opposed to losses? The test was performed using an experiment with a translation of the origin of the payoffs to a "gains" environment.

First, subjects were paid $10 up-front and were given 1000 units of money (m) and 20 units of inventory (x) as initial holdings. Secondly, their incentives to trade were formulated in terms of potential gains:
Total Gain = Gain A + Gain B
Gain A = $<(1/100)\ m>$ and
Gain B = $<0\ \{\text{Prob } 1/2\}$ or $(100 \text{ cents})x\ \{\text{Prob } 1/2\}>$.

Thus the purchase of a unit of X is simply the purchase of a lottery that yields a 50:50 chance between 100 cents and 0. Note that for both types of design (losses and gains) the ex-ante expected amounts of money a subject could earn were the same. Thus, since the final states of the world are the same under both conditions, stable preferences over final states of the world yield should produce behavior that is the same for both types of experiments. The nine subjects who were used in this second control experiment had participated in the first additional control experiment 0509 (One of the ten subjects that participated in 0509 could not return for the experiment 0516). Recall, these subjects when participating in experiment 0509 demonstrated clear risk seeking behavior in losses as they had done in the previous experiments. Therefore, if no differences exist for the subjects between losses and gains, one would also expect to observe risk seeking behavior in the "gains" and thus prices should be above the "expected value'. Prices above the risk neutral level of 50 would reflect the buying efforts of risk seeking individuals who drive the price up because they enjoy the variance in wealth. On the other hand, if the subjects have asymmetric risk attitudes in the gains and losses, then the subjects would switch to the risk averse behavior when the lotteries are formulated in terms of gains. As a consequence , the transaction prices in the second additional control experiment (0516) would be below the risk neutral level of 50.

Figure 16 presents time series of transaction prices for the second additional control experiment (0516). The horizontal line corresponds to the risk neutral level of 50 cents. Notice that all transaction prices are below 50.[4] There are an odd number of agents and if more than half are risk seeking then the prices must necessarily be above the fair lottery price of 50. Thus, the market measure suggests risk aversion on the part of subjects as opposed to risk seeking. This asymmetry in behavior is supported at the individual level. Three of the four subjects who demonstrated risk averse behavior in 0516 (the gains) by selling the lottery at prices below the risk neutral price had exhibited strong risk seeking tendencies by selling insurance at a price below the risk neutral prices, when participating in 0509 (the loss). These individuals exhibited clear asymmetric behavior by switching to risk averse behavior when the market consists of the same lotteries only

[4] The data are (period, average price, std.dev.) : (0,45,2.15), (1,47,1.34), (2,48,.83), (3,48,1.28), (4,48,.83), (5,48,.5), (6,48,.46), (7,48,.48).

transformed to the gains.[5] Thus, the hypothesis that the subjects were risk seeking in general and exhibited no asymmetric behavior, can be rejected.

A glance at the time series of all experiments suggests the motivation for a third set of additional control experiments. Notice that prices in all experiments tend to be below the equilibrium value of the model. This suggests the hypothesis that something about the experiments, unrelated to risk preferences, simply caused the markets to converge from below. A third set of four additional control experiments were performed but are not reviewed here in detail. The purpose of the experiments was to control for the hypothesis that the "natural path" of convergence of any market in these environments is from "below". These experiments were identical to the other experiments in the loss domain except the numeraire were switched from money to the lottery and the units were changed to accommodate the switch.[6] If risk seeking behavior is present then prices should be <u>above</u> the equilibrium price of 200. Thus the same theory of risk seeking that predicted below risk neutral prices now predicts prices above the risk neutral equilibrium price level.

Four experiments were conducted with inexperienced and then experienced subjects. Because this switch in numeraire was evidently difficult for subjects, the processing and analysis of the data require more space than is available in this paper. However, the conclusion from analysis is that with experienced subjects some support exists for the presence of risk preferring subjects in this "inverted" environment. These data are not conclusive but they do help to reject any presumption that for some reason prices are always below risk neutral levels whether in the gains or losses. Prices of money in terms of the "insurance", when experienced people were used, tended to be above the risk neutral levels.

A paradox can be observed in the data. On one hand the individuals selected for experiment 0509 continued to exhibit risk seeking behavior throughout the second experience. On the other hand data exists that suggest an evolution of risk attitudes when experience becomes a factor. In other words, for many subjects, the risk attitudes after experience, might be different from those initially. For example, Figures 7-15 show that in most of the experiments price convergence was occurring in the training periods. The early prices were consistently lower suggesting that people were becoming more risk averse as they gained experience (and also faced actual payoffs). The following two conjectures represent an attempt to approach the problem of changing behavior with experience. The conjectures should not be interpreted as results but rather as a starting point of a discussion about this complex issue.

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[5] Because prices are endogenous, the model itself indicates that market experiments of the type studied here can only yield limited opportunities to classify individuals according to preferences. Three individuals were sellers in the loss and buyers in the gain clearly exhibited the asymmetry of preferences suggested by extended prospect theory. One individual was a buyer in loss and a buyer in gain so exhibited behavior that was consistent with asymmetric preferences but of course could also have been consistently risk averse. Two individuals were sellers in the loss and buyers in the gain so were consistent with asymmetric preference but are also consistent with general risk seeking. Three individuals were buyers in the loss and buyers in the gains and thus cannot be classified at all since they are consistent with all modes of preference.

[6] $m^{\bullet} = 2000$, $x^{0} = 10$; Loss A = < 0 {Prob 1/2} or \$40 - (1/100)m {prob 1/2}>, Loss B = \$20 -x . The risk neutral price of x in terms of m is 200.

CONJECTURE 1. Support of specific implications of the loss aversion axiom of prospect theory, such as an "endowment effect", "status quo bias" or "tradeoff vs. improvement" is stronger in the experiments involving inexperienced subjects and disappears with experience.

SUPPORT. The result is a direct implication of the data presented in Table 8. The source of support is a comparison of the behavior of the subjects who participated in the experiments 0316, 0317, 0501, 0502 and 0505 as inexperienced subjects, with their behavior when they participated in the experiments 0324 and 0509. The latter behavior was substantially different from the former. Such a difference in behavior of the same people participating in the same experiment, suggests that experience matters.

As was discussed in the support of Result 2, in the first set of experiments (subjects were inexperienced) the final holdings of eight of twenty subjects were near the origin (less than 10 units were traded), implying status quo bias. In other words the status quo was the chosen option for the subjects. At the same time, however, the phenomena cannot be due to the status quo bias as derived from prospect theory. At the prices that existed in these markets, if people are risk seeking as they must be under the conditions of prospect theory from which the status quo bias is derived, the competitive equilibrium have individuals only on the boundaries selling insurance. Thus while a status quo bias is observed it cannot be due to prospect theory. At the same time, in the second set of experiments (subjects were experienced) the final holdings of only four of twenty subjects were near the origin, implying boundary final holdings as predicted by the competitive model and in agreement with other experiments.
Moreover, fifteen of the twenty subjects increased the absolute values of their final holdings during their second experiment. The conclusion is that inexperienced the subjects in the experiments demonstrated a tendency to make very few changes in their holdings. With experience and understanding their behavior changed. Thus degree of experience and not a status quo bias derived from prospect theory accounts for their behavior.●

The conjecture above suggests that when people do not feel confident about their understanding of a situation they will be conservative and chose inaction over action. It is possible to use prospect theory to explain such phenomena. The explanation could go as follows. A natural feature of uncertainty, as opposed to risk, is the possible existence of negative prospects that are possibly weighted so high that inaction results. With exposure to the decision environment comes a better understanding and as a consequence the imagined, possibly negative prospects disappear and the other features of the decision process emerge. While this explanation is crude, it appears that some such modification of prospect theory is necessary for the last result to be explained.

The discussion and results above hold implications about the nature of circumstances under which prospect theory can be applied in its current form. Since the real prospect theory (and not the extended prospect theory examined here) is about a decision process, it might not be surprising if the nature of the axioms/laws of the process is subject to evolution with experience and understanding. The conjecture developed next suggests that some of the central phenomena identified by prospect theory are not a stable features of human choice behavior. They go away with experience and perhaps with reflection.

CONJECTURE 2. With experience, risk seeking in the losses evolves into either risk neutral or risk averse behavior.

SUPPORT. Price convergence from below in most experiments (Table 3) suggests that the incidence of risk seeking behavior is getting weaker as the experiment continues. The competitive model implies (Propositions 4-6), that the more RS subjects are in the system the less will be the equilibrium price and the more RA subjects are in the system the higher will be the equilibrium. Table 3 shows that the prices were consistently increasing in 7 out of 9 MN experiments. Although it is impossible to claim that Risk-Seeking behavior always disappears with experience, obvious tendencies of the phenomena were observed in four experiments.•

The above conjectures are of potential importance because they help isolate the nature of the decision process and its possible relationship to properties of an individual. Convergence in economic environments seems to occur at many different levels. Clearly prices and quantities have a convergence property. However, individual decision rules seem to evolve and individual understanding of a situation and the attitudes of other individuals seem to undergo a transformation during the course of decisions and market activity.

A hypothesis/philosophy has been advanced to describe this evolution , called the discovered preference hypothesis Plott, (forthcoming), and while that hypothesis is so simple that it is not likely to survive close examination, the above two conjectures seem to be part of a pattern that the discovered preference hypothesis was advanced to capture. The idea is the individuals have a consistent set of preferences over states but such preferences only become known to the individual with thought and experience. Individuals at first exhibit a type of myopia, choosing in a somewhat impulsive way reflecting their immediate perceptions of their interests. With experience behavior moves toward patterns of choice behavior typical of the predictions of classical preference theory. Thus, when individuals are first given questions, they are characterized by a type of confusion. As they begin to formulate decisions while in this state they are influenced by "frames" in much the way that prospect theory asserts. As an understanding of the context evolves, the manifestation of the underlying preferences becomes more clearly observable in the data and decisions approach those of the classical theory of choice and preference.

7. CONCLUSIONS

This research began with questions motivated by psychological research. Prospect theory has had a considerable impact on the decision literature. The question posed by the research reported here was whether or not the predictions of an " extended prospect theory" could find support in markets.

Exchange economies were created in which only losses could occur. Preferences over losses were not controlled in the unusual manner in which preferences are induced. Instead the objective was to determine if the "preferences revealed" by market actions had properties that one might expect from having studied the psychological based literature.

Risk seeking behavior in the loss domain was observed in the markets studied. Its existence lends support to two fundamental properties of prospect theory. First, since risk averse behavior has been widely documented in the positive domain in experimental markets, we can conclude that there is an asymmetry between gains and losses. A single control experiment reported in the paper further supports that pattern. That asymmetry is a fundamental property of prospect theory. As a corollary, we can conclude that there are such things as "gains" and "losses", as opposed to only "final states of the world", the existence of which implies the existence of another fundamental feature of prospect theory, a reference point. Finally, we can conclude that risk seeking in the losses is a frequent occurrence. It was a property of over one third of the people observed in these markets.

The patterns of results lend strong support to features of prospect theory as decision process. The more fundamental question to be posed is whether individuals are ONLY a bundle of decision processes, rules of thumb that have no necessary relationship to an underlying attitude or coherence of an underlying preference. First it should be emphasized that a pattern of coherence is evident in the markets. Convergence to understandable equilibria occurred. It follows that the "reference point" was not so subject to moment to moment "framing" that preferences became so labile that they had no coherence. These markets behaved as if a large proportion of individuals had reasonably coherent and stable preferences. Of course, a large proportion of these preferences were exactly of the form that one would have expected from a reading of prospect theory, as stated by the "extended prospect theory".

Psychologists have long maintained that a relevant domain of prospect theory is "one time decisions". The results reported here support that presumption and stimulate a question regarding whether or not that is the only circumstance in which the theory applies. The conjectures reported here suggest that the first impulses experienced by a decision maker would seem to be described by the theory. Features of prospect theory are clearly present when people are confused. The support for the status quo bias is an example. The difference in behavior of those that give a risk seeking response to a questionnaire as opposed to those that give a risk averse response is another body of evidence that conservatism is a consequence of incomplete understanding. After all, the theory is about a process of decision, so it is not particularly surprising that its features are most evident in situations in which individuals are involved in a process of decision.

Whether or not "considered opinions" are governed by the same processes as are immediate impulses involves deeper and more complex experiments than have been performed to date. The final conjecture of the paper is that some of the features of prospect theory will disappear with practice or perhaps even with reflection. In particular, the conjecture is that risk seeking in the losses is a property of inexperience that will give way to risk averse behavior. Of course one implication of the conjecture is that the concept and importance of a reference point will also fade. The idea that the evolution of attitudes has a direction toward the more classical lines of preference theory has been vigorously criticized (Kahneman, forthcoming). Nevertheless, the data presented here provides additional support for such a presumption.

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APPENDIX 1

Please answer the following questions reflecting your own preferences. There are no right or wrong answers to these questions.

Q1: Choose between winning

A:	\$1000	with probability .5	B: \$500 with certainty
	\$0	with probability .5	

CIRCLE YOUR ANSWER: A B

Q2: Choose between winning

C:	\$40	with probability .5	D: \$20 with certainty
	\$0	with probability .5	

CIRCLE YOUR ANSWER: C D

Q3: Choose between winning

E:	\$4000	with probability .8	F: \$3000 with certainty
	\$0	with probability .2	

CIRCLE YOUR ANSWER: E F

Q4: Choose between winning

G:	\$15	with probability .5	H: \$7.50 with certainty
	\$0	with probability .5	

CHOOSE YOUR ANSWER: G: H:

Q5: Choose between winning

I:	\$2	with probability .5	J: \$1 with certainty
	\$0	with probability .5	

CIRCLE YOUR ANSWER: I J

Q6: Choose between <u>losing</u>

K:	\$1000	with probability .5	L: \$500 with certainty
	\$0	with probability .5	

CHOOSE YOUR ANSWER: K L

Q7: Choose between <u>losing</u>

M: $40	with probability .5	N: $20 with certainty
$0	with probability .5	

CHOOSE YOUR ANSWER: M N

Q8: Choose between <u>losing</u>

O: $4000	with probability .8	P: $3000 with certainty
$0	with probability .2	

CHOOSE YOUR ANSWER: O P

Q9: Choose between <u>losing</u>

Q: $15	with probability .5	R: $7.50 with certainty
$0	with probability .5	

CHOOSE YOUR ANSWER: Q R

Q10: Choose between <u>losing</u>

S: $2	with probability .5	T: $1 with certainty
$0	with probability .5	

CHOOSE YOUR ANSWER: S T

APPENDIX 2

Name________________________________

SSN_________________________________

Phone ________________________________

Identification number ______________

t = _________

INSTRUCTIONS

You are about to participate in an experiment. For your agreement to participate you will be paid $60. The structure of the experiment is such that you will be exposed to a possible money loss. The amount of loss will depend upon your decisions and the outcome of the lottery as will be explained in the following paragraphs.

Your total money loss will consist of two different types of losses

Total Loss = Loss A + Loss B

Loss B will be determined as $20 minus your B-Dollar holdings.

Loss A will be determined by the outcome of a lottery. The outcome of the lottery is determined by a single draw from an urn that contains equal number of RED and BLACK balls.

If the drawn ball is a RED one then your Loss A is zero.

If the drawn ball is a BLACK one then your Loss A will be determined as $40 minus 1/100 times your A-Cent holdings.

The experiment will consist of a series of periods. At the beginning of each period you will be given 2000 A-Cents and 10 B-Dollars. The B-Dollars reduce your money Loss B. The A-Cents reduce your money Loss A should a BLACK ball be drawn but of course A-Cents are worth nothing to you should a RED ball be drawn. During the period you will be able to change the nature of your Losses by exchanging A-Cents for B-Dollars and B-Dollars for A-Cents.

Each 1 B-Dollar held at the end of a period reduces your B-Loss by 1\$ and each 100 A-Cents reduces your A Loss by \$1 should a BLACK ball be drawn.

As you may have noticed the chance that the drawn ball is BLACK is 1/2 or 50% and the chance that the drawn ball is RED is also 1/2 or 50%. You may also have noticed that B-Dollars are always worth something to you (1 B-Dollar reduces \$1 of B Loss not depending of the outcome of the lottery) and that you need A-Cents only in 50% of cases (100 A-Cents reduces \$1 of A Loss only if a BLACK ball is drawn).

As described above the maximum possible B Loss is \$20 (happens if you have no B-Dollars at all) , the maximum possible A Loss is \$40 (happens if you have no A-Cents at all and the BLACK ball is drawn). That implies that the maximum amount of A-Cents you may want to have is 4000 A-Cents and B-Dollars is 20 B-Dollars.

The A-Cents that you have at any time are found in the CASH on HAND space on your computer screen. The B-Dollars that you have are found in the INVENTORY space on your computer screen. So if you buy one unit of INVENTORY at a price P you give up P A-Cents and you acquire 1 B Dollar. If you sell one unit of INVENTORY at a price P you acquire P A-Cents and you give up 1 B-Dollar.

The CASH ON HAND (A-Cents) and INVENTORY (B-Dollars) held at the end of a period will dictate the terms of your lottery that resulted from the trades you made during the period. These dictate the nature of your loss. Nothing can be transferred from one period to another. The trading in each period yields the terms of a specific lottery. The results of only one period will be used to determine your Loss. At the end of the experiment a special lottery will be held to determine which of several periods it will be. In this special lottery each period will be given equal weight.

EXAMPLE 1

Suppose for example that you made no trades at all during the period. So your final holdings are the same as initial holdings: 2000 A-Cents (CASH on HAND) and 10 B-Dollars (INVENTORY).

If a BLACK ball is drawn you would have lost:

-------- **A Loss** ----------------------------- --------- **B Loss** ---------

\$40 - 1/100 X 2000 (the A-Cent held) plus \$20 - \$10 (the B-Dollars held) = \$30

If a RED ball is drawn you would have lost:

-------- **A Loss** ----------------------------- --------- **B Loss** ---------

\$0 plus \$20 - \$10 (the B-Dollars held) = \$10

After each period you will have to fill out the RECORD of LOSSES enclosed in your instruction folder. For example if in some period you acted as described in Example 1 your RECORD of LOSSES should be as follows:

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B-Loss $20 minus #B-Dollars	Your A-Loss $40 minus #A-Cents / 100	Total loss if the ball is BLACK (A+B)	Total loss if the ball is RED (A)	Real total loss
0	Beg.	10	2000	$10	$20	$30	$10	
0	End.	10	2000	$10	$20	$30	$10	

EXAMPLE 2

Suppose now that during the period you have sold 8 B dollars at price 220 each. That means that your final holdings are: 2 B dollars (10 - 8) and 3760 A-Cents (2000+8x220).

If a BLACK ball is drawn then you would have lost:
$40-$37.6 (A Loss)+ $20-2 (B-Loss)=$20.4 (Total Loss)

If a RED ball is drawn then you would have lost:
$0 (A Loss)+ $20-2 (B-Loss)=$18 (Total Loss)

Your RECORD of LOSSES in this case should be filled out as follows:

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B-Loss $20 minus #B-Dollars	Your A-Loss $40 minus #A-Cents / 100	Total loss if the ball is BLACK (A+B)	Total loss if the ball is RED (A)	Real total loss
0	Beg.	10	2000	$10	$20	$30	$10	
0	End.	2	3760	$18	$2.4	$20.4	$18	

The above the example shows how you may change the nature of your losses by selling B-Dollars compared to making no actions at all (Example 1). Namely in the Example_l your gains were the following:

50% chance of losing $30 (a BLACK ball is Drawn)

50% chance of losing $10 (a RED ball is drawn)

After selling 15 B Dollars at the price of 50 each (Example 2) your losses are determined as:

50% chance of losing $20.4 (a BLACK ball is drawn)
50% chance of losing $18 (a RED ball is drawn)

Now you can see how your actions during the experiment may change the nature of your losses.

EXAMPLE 3.

Suppose that during the period you bought 10 B-Dollars at a price 190 each. That means that your final holdings are: 100 A-Cents (2000-10x 190) and 20 B-Dollars (10+10).

If a BLACK ball is drawn you would have lost:

$40-1 (A Loss) + $20-20 (B Loss)= $39 (Total Loss)

If a RED ball is drawn you would have lost:
$ 0 (A Loss) + $20-20 (B Loss)= $0 (Total Loss)

So your losses in this example are the following:

50% chance of losing $39 (a BLACK ball is drawn)
50% chance of losing $0 (a RED ball is drawn)

Your RECORD of Losses should be filled out as follows:

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B-Loss $20 minus #B-Dollars	Your A-Loss $40 minus #A-Cents / 100	Total loss if the ball is BLACK (A+B)	Total loss if the ball is RED (A)	Real total loss
0	Beg.	10	2000	$10	$20	$30	$10	
0	End.	20	100	$0	$39	$39	$0	

Compare it to the losses from Examples 1 and 2.

Exercise 1.

Suppose that during the period you sold 9 B-Dollars at the price of 210 each. Compute

i. Your final B-Dollar holding ________________________________

ii. Your final A-Cent holding ________________________________

iii. Your A Loss ________________________________

iv. Your B Loss________________________________

v. Your Total Loss if a BLACK ball is drawn ________________________

vi. Your Total Loss if a RED ball is drawn ________________________

So your final lottery is

50% chance of losing ______________
50% chance of losing ______________

vii. Fill out the RECORD of Losses for the above case.

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B-Loss \$20 minus #B-Dollars	Your A-Loss \$40 minus $\frac{\text{\#A-Cents}}{100}$	Total loss if the ball is BLACK (A+B)	Total loss if the ball is RED (A)	Real total loss
0	Beg.							
0	End.							

Exercise 2.

Repeat Exercise 1 for the case when during a period you bought 6 B-Dollars at the price of 180 each.

i. Your final B-Dollar holding ______________________________

ii. Your final A-Cent holding ______________________________

iii. Your A Loss ______________________________

iv. Your B Loss______________________________

v. Your Total Loss if a BLACK ball is drawn ____________________

vi. Your Total Loss if a RED ball is drawn ____________________

So your final lottery is

50% chance of losing ____________
50% chance of losing ____________

vii. Fill out the RECORD of Losses for the above case:

Period #		Your B-Dollar holding (Inventory)	Your A-Cent holding (Cash on Hand)	Your B-Loss \$20 minus #B-Dollars	Your A-Loss \$40 minus #A-Cents / 100	Total loss if the ball is BLACK (A+B)	Total loss if the ball is RED (A)	Real total loss
0	Beg.							
0	End.							

APPENDIX 3. Proofs.

SUPPORT of the PROPOSITION 1. The indifference curves are determined by the following equation:

$$0.5U(m/100 - 20) + 0.5\,U(m/100 - 20 + x - 40) = C, \qquad (1)$$

were $0 \leq m \leq 2000$ and $0 \leq x \leq 40$ are the money M and the inventory X holdings respectively by the end of a period. To determine the shape of the indifference curves x'_m and x''_{mm} are to be computed. By differentiating both sides by m we get:

$$0.01U'(m/100-20) + U'(m/100+ x - 60)\,(x'_m + 0.01) = 0 \qquad (2)$$

$$x'_m = -0.01 - 0.01U'(m/100-20)/U'(x + m/100 - 60) \qquad (3)$$

Differentiating both sides of (2) by m implies:

$$0.01U''(m/100-20) + 100U''(m/100+x-60)(x'_m+1)^2 + 100U'(m/100+x-60)x''_{mm} = 0$$
(4)

Substitution of (3) into (4) gives:

$$x''_{mm} =(-10^{-4})/U'(m/100+x-60)[U''(m/100-20)+U''(m/100+x-60)\{U'(m/100-20)/U''(m/100+x-60)\}^2]$$
(5)

By substituting into (5) the properties of the derivatives listed in the hypothesis of the proposition the first three conclusions of the proposition follow immediately. One may also notice that for all types of subjects

$$U'(x=40, m=0)= -0.02 \text{ and } -0.01 \leq U'(x, m=20) \leq -0.02. \qquad (6)$$

From this the fourth conclusion of the proposition follows.●

Proof of the PROPOSITION 3. Figure 4 shows the shape of the total excess demand in this case.
For every i, since all subjects are risk averse, $Q_i(50)=20>0$ and $Q_i(+\infty)<0$, and $D(50)>0$ and $D(+\infty)<0$.
The continuity of $Q_i(p)$ implies the continuity of $D(p)$, which in turn implies that there exists p^* such that $50<p^*<+\infty$ and $D(p^*)=0$. •

Proof of the PROPOSITION 4. Figure 5 shows how the total excess demand changes if N ($N \geq A$) risk neutral subjects are added to the system. For the risk neutral subjects the excess demand function takes values in the interval from -20 to +20 ($Q_i(50)=[-20;20]$). . For the risk averse subjects $Q_i(50)=20$. Thus at price p=50 the total excess demand correspondence is equal to the interval $[d_1;d_2]$. That is $D(50) = [d_1;d_2]$, where $d_1=-20N+20A$ and $d_2=20(A+N)$. If $A>N$ then $0<d_1<d_2$ and the proposition is reduced to the Proposition 3. If $A \leq N$ then $d_1 \leq 0 \leq d_2$. The proposition is proved , since at the price of 50 the total excess demand function has a value of 0 ($0 \in D(50) = [d_1;d_2]$). •

Proof of the PROPOSITION 5.. Figure 6 shows the total excess demand function when S,A and N are greater than 0.
Notation:
$\Pi=\{p_1 ,..., p_L\}$ - set points of discontinuity of D(p) ($p_j<50$ for any j and $L \leq S$) in increasing order.
n_j is the number of the individuals whose demand is discontinuous at $p_j \in \Pi$
We need to prove that there exist a p^* such that $D(p^*)=0$.

Let us note that $D(\infty) < 0$.
First, let us determine the total excess demand $D(p)$ at $p=50$. By definition $D(p)=\Sigma Q_i(p)$. For the risk neutral subjects $Q_i(50)\in[-20;20]$. For the risk averse subjects $Q_i(50)=20$. For the risk seeking subjects $Q_i(50)=-20$.
Repeating the similar argument in Proposition 4, at $p=50$ $D(50) = [d_1;d_2]$ where $d_1= -20(N+S)+20A$, $d_2=-20S+20(A+N)$.
If $d_2>0$ ($S<A+N$) then for the two possible cases ($d_1\leq 0 < d_2$ and $0<d_1\leq d_2$) the proof is similar to the proofs of the Proposition 3 and 4. The equilibrium price is greater than or equal to 50.
If $d_2=0$ ($S=A+N$) then 50 there exist multiple equilibria. First, notice that 50 is an equilibrium price. Secondly, if the price is above 50 then supply is always greater than demand. Therefore no equilibria exist. On the other hand if the price falls a little below 50 then demand is still equal to supply. This continues until all risk seeking people are willing to sell. Therefore there exist an interval [a ; 50] of equilibrium prices, where $0 < a < 50$.
Finally, let us consider the case when $d_2<0$ i.e. $S>A+N$.
The correspondence $D(p)$ is strictly positive at the price equal to 0 ($D(0)=20(N+S+A)$, strictly negative at the price equal to 50 ($D(50) = [d_1;d_2]$ and $d_2<0$) and has L points of discontinuity at the interval [0;50]. It will be shown that the set of the values of $D(p)$ on the above interval is a set of S+1 consecutive integers from $40K_1$ to $40K_L$, where $K_1=(N+A+S)/2$ (positive) and $K_L=(A+N-S)/2$ (negative).

Secondly, let us construct $D(p)=\Sigma Q_i(p)$ for $p\in[0,50)$. For the risk averse and risk neutral subjects $Q_i(p)=20$ if $p\in[0,50)$. Thus, the only subjects whose excess demand functions have different values in the interval are risk seeking ones. For a risk seeking subject $Q_i(p)=\{20 \text{ if } p<p_j, -20 \text{ if } p>p_j, 20 \text{ or } -20 \text{ if } p=p_j\}$, where $p_j\in\Pi$. This implies that $D(p)$ is constant in any open interval $(p_j;p_{j+1})$. One may notice that there are L+1 such intervals, since there are L points of discontinuity. Let us denote $D(p)=40K_j$ if $p\in(p_{j-1};p_j)$. At $p=p_j$, n_j of risk seeking subjects are indifferent between +20 and -20. Thus, the total excess demand of those n_j subjects at the price p equal to p_j is the set of n_j+1 integers: $\{20n_j, 20n_j-40, \dots, -20n_j\}$. Moreover, the total excess demand of the same n_j subjects is equal to $20n_j$ if p is less than p_j and is equal to $-20n_j$ if p is greater than p_j. The total excess demand of everybody else is constant near p_j. This implies that $D(p_j-\varepsilon)-D(p_j+\varepsilon)=40(K_{j+1}-K_j)=20n_j-(-20)n_j=40n_j$. Thus all K_j can be determined by induction. Formally:

If $p\notin\Pi$; $p_{j-1},p_j\in\Pi$, $p\in(p_{j-1};p_j)$ then $D(p)=40K_j$, $j=1 \dots L$

where K_j is defined as follows:
$K_1=(A+N+S)/2$ [Positive Integer, since there is an even number of subjects]
$K_{j+1}=K_j - n_j$

If $p\in\Pi$; $p=p_j$ then $D(p)=\{40K_j, 40(K_j-1), \dots, 40K_{j+1}\}$

Thus at the interval [0;50) D(p) has the following values:
$40K_1, 40(K_1-1), \dots, 40K_L$, where $K_1=(A+N+S)/2>0$ and $K_L=K_1-\Sigma n_j=K_1-S=(A+N-S)/2 < 0$. This implies that one of the values is zero.
The proposition is proved. •

Indifference Curves and Budget Constraints of a Risk Averse Person

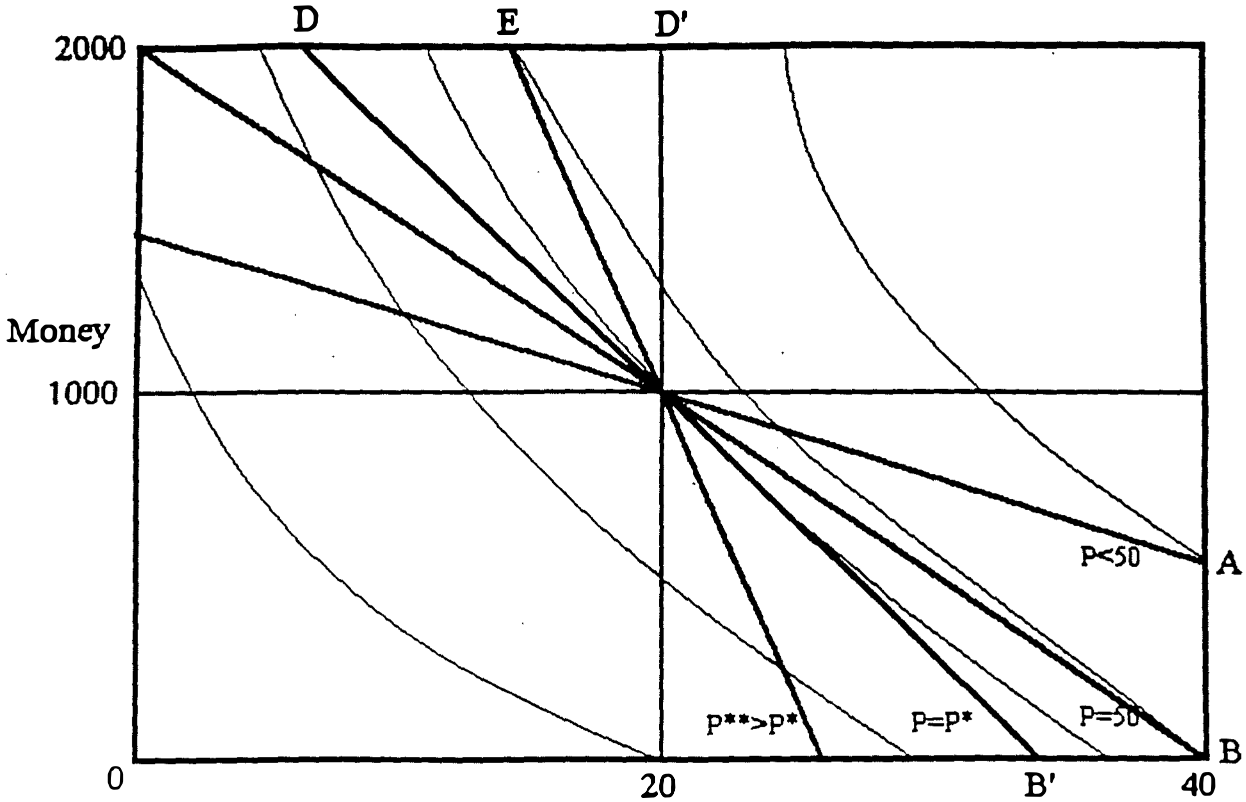


Figure 1a.

Demand Curve of a Risk Averse Person

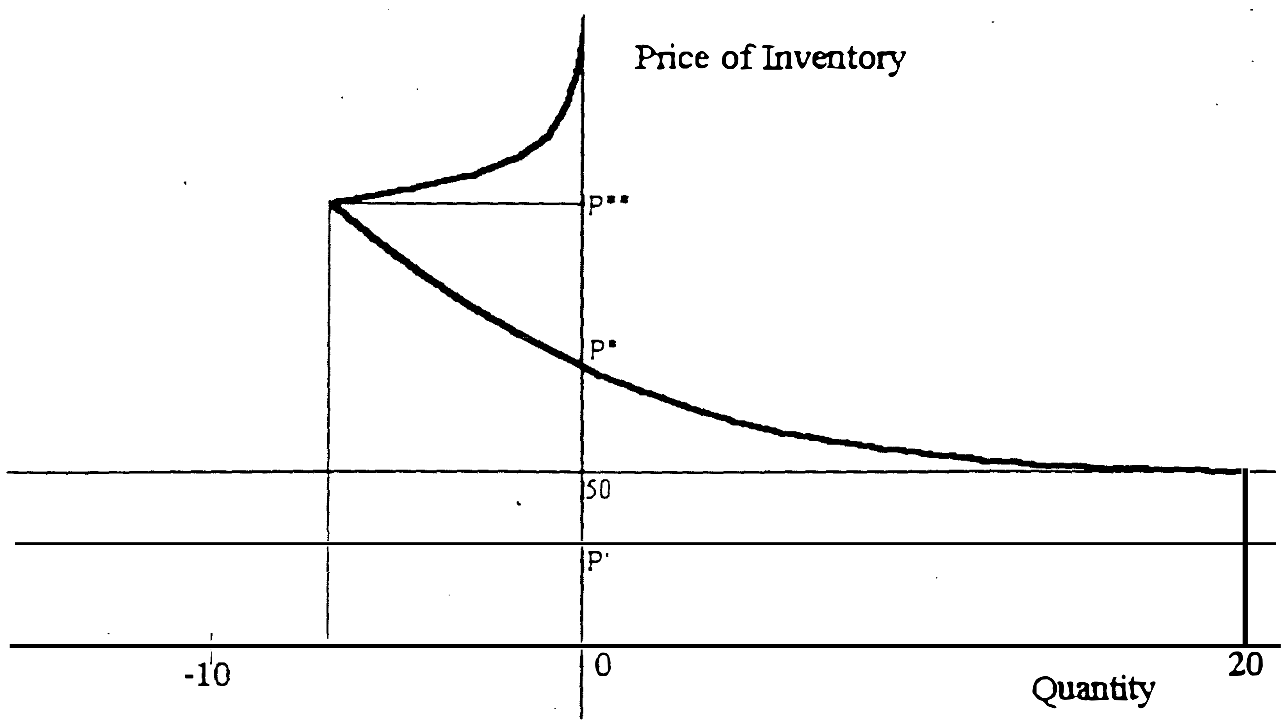


Figure 1b.

Indifference Curves and Budget Constraints of a Risk Seeking Person

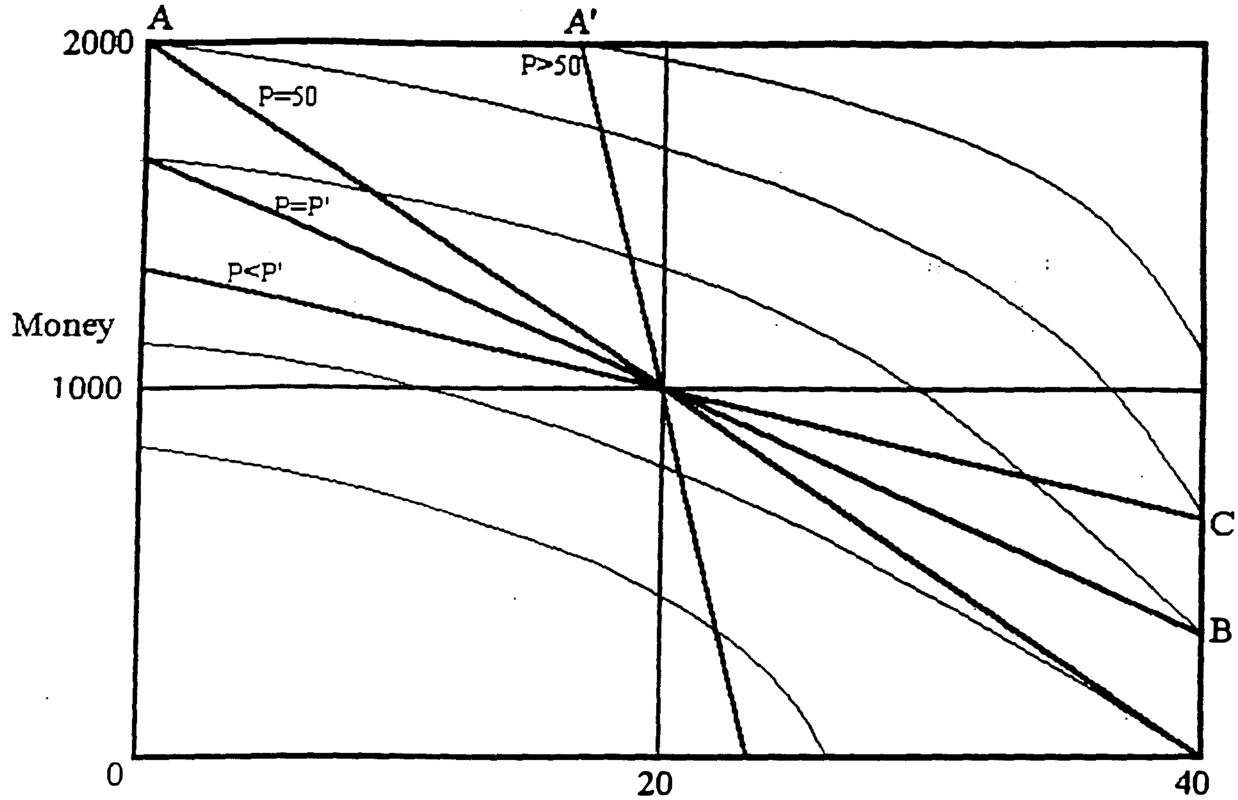


Figure 2a.

Demand Curve of a Risk Seeking Person

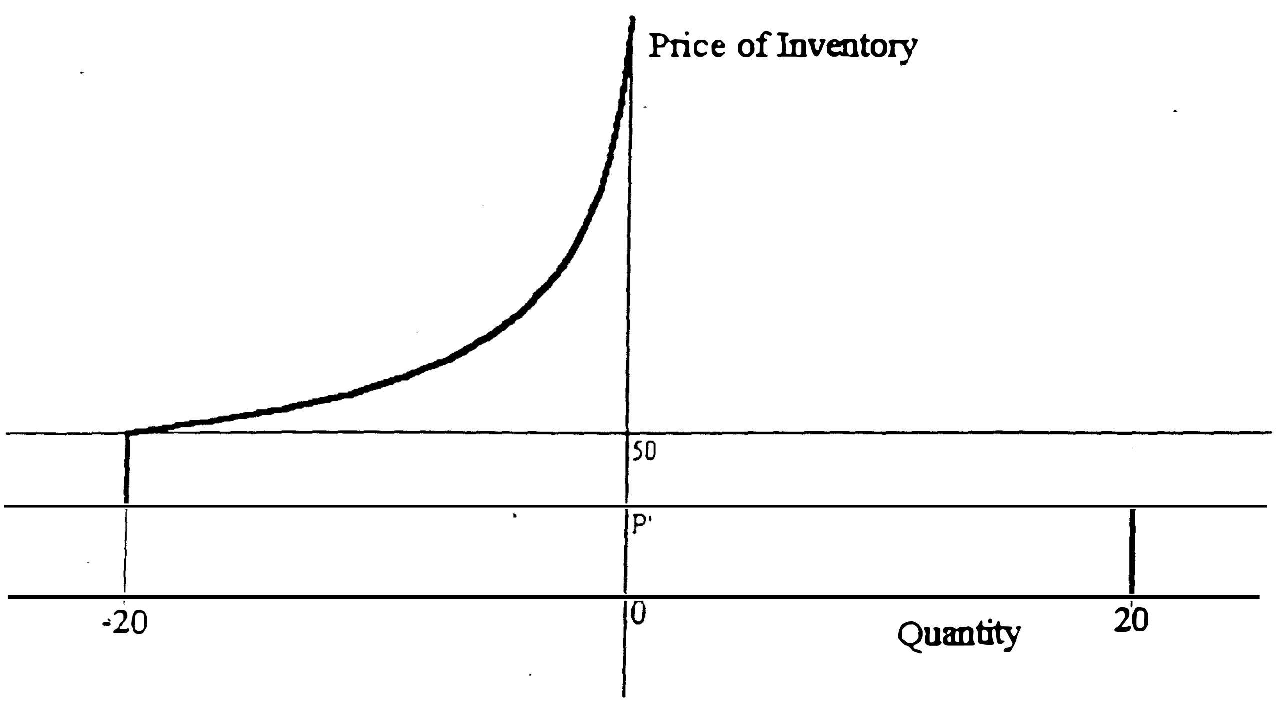


Figure 2b.

Indifference Curves and Budget Constraints of a Risk Neutral Person

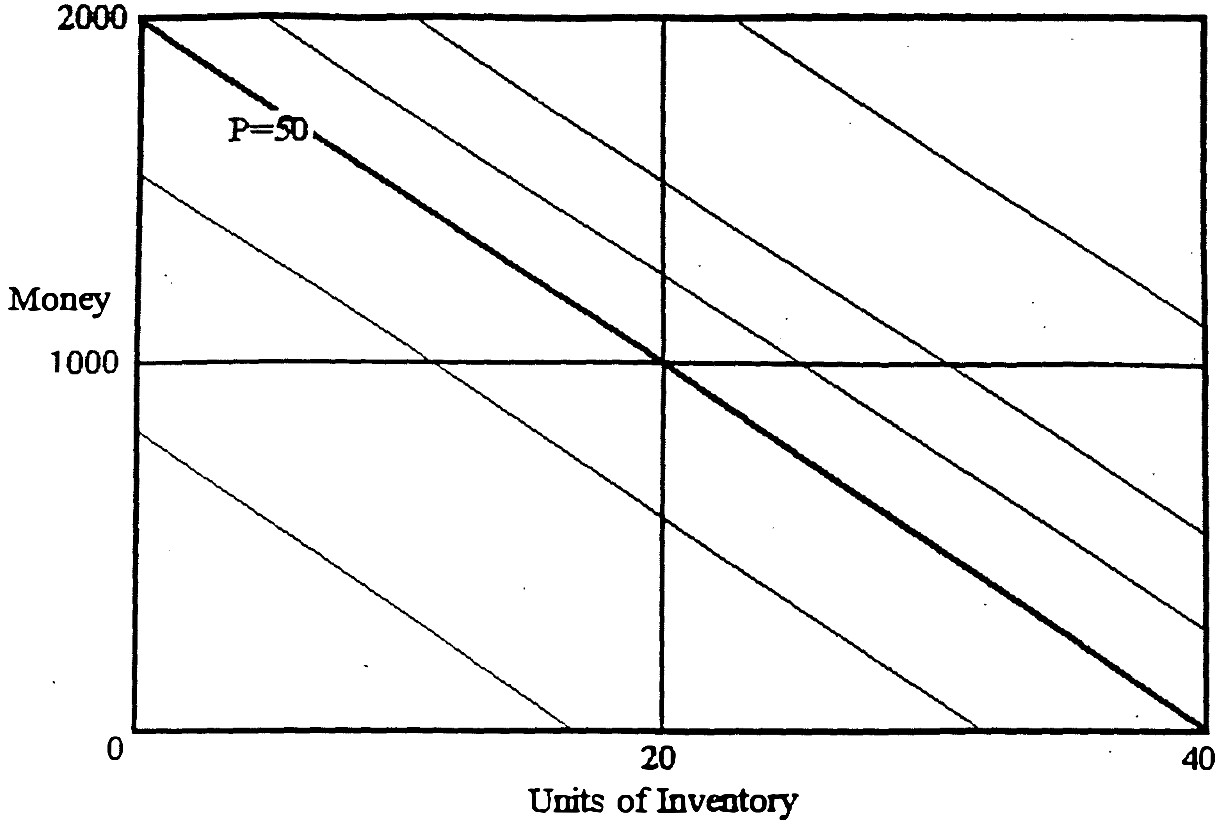


Figure 3a.

Demand Curve of a Risk Neutral Person

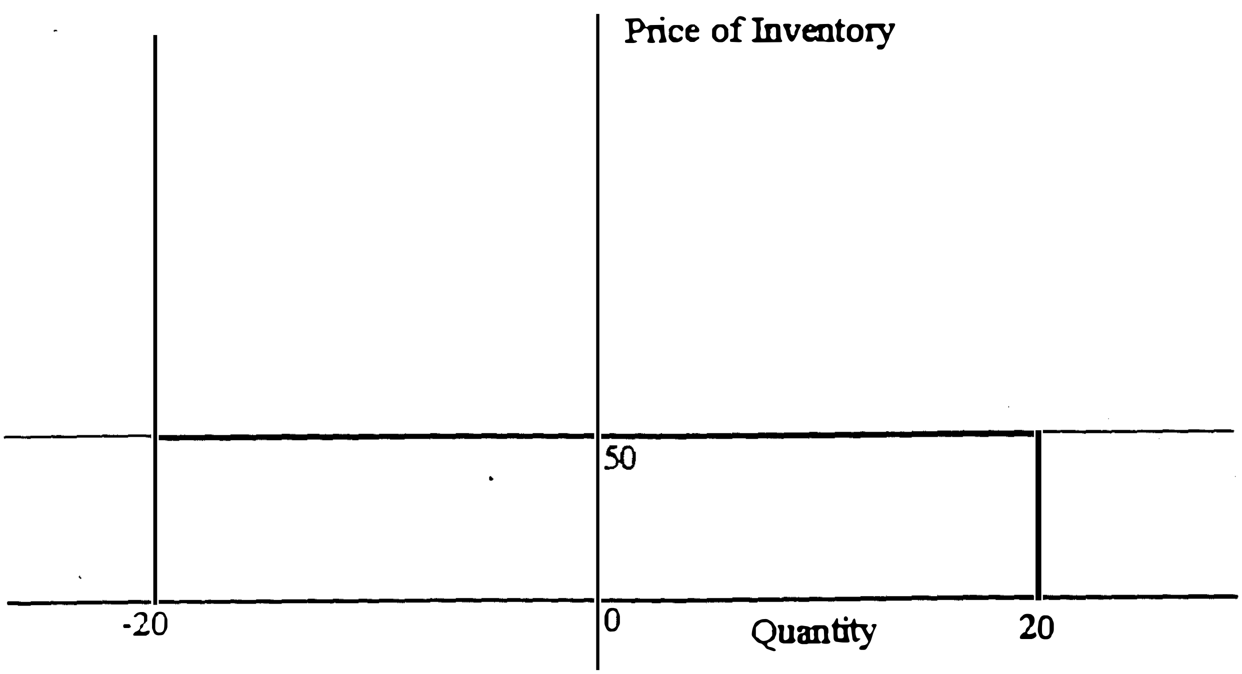


Figure 3b.

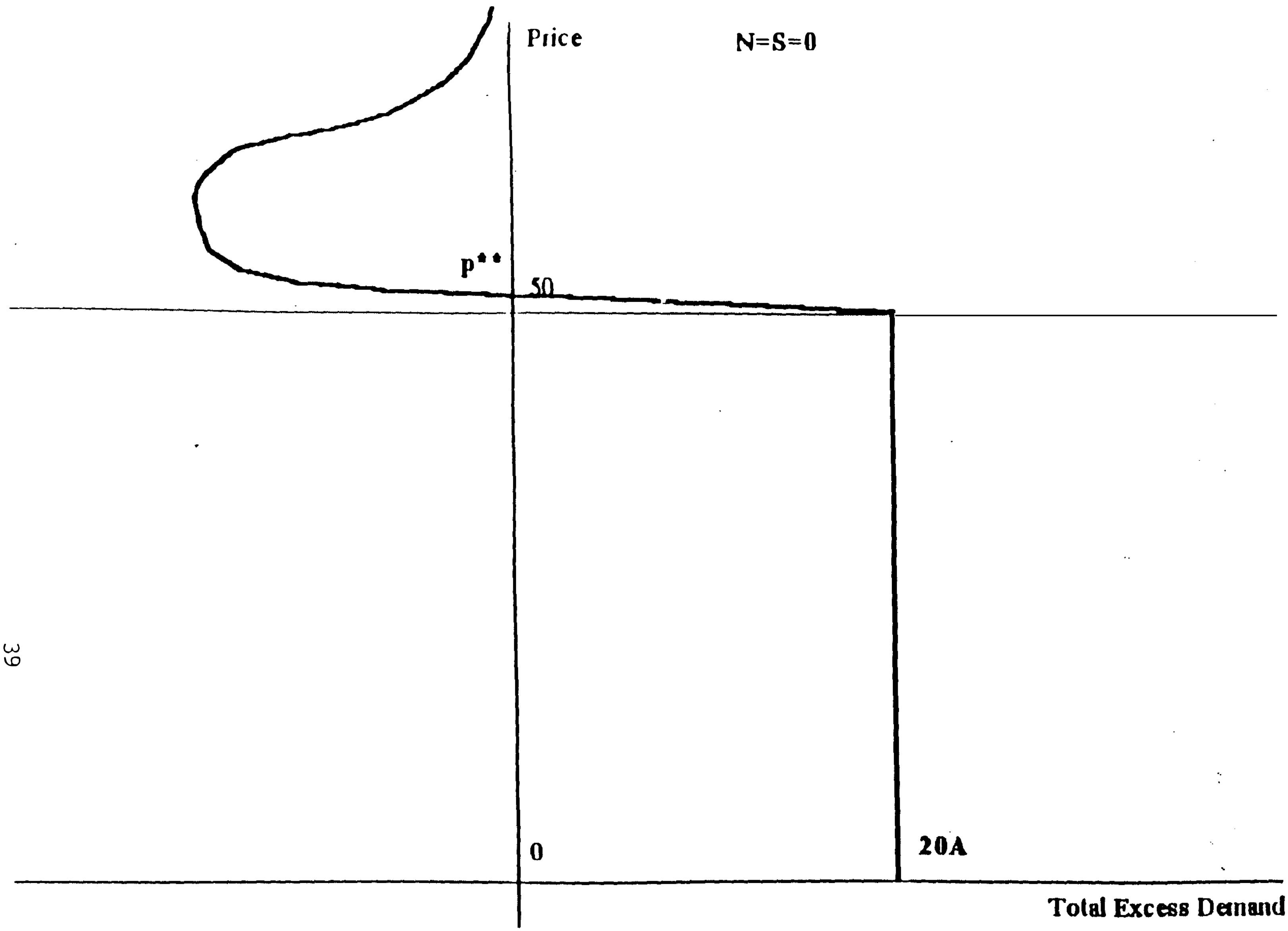


Figure 4.

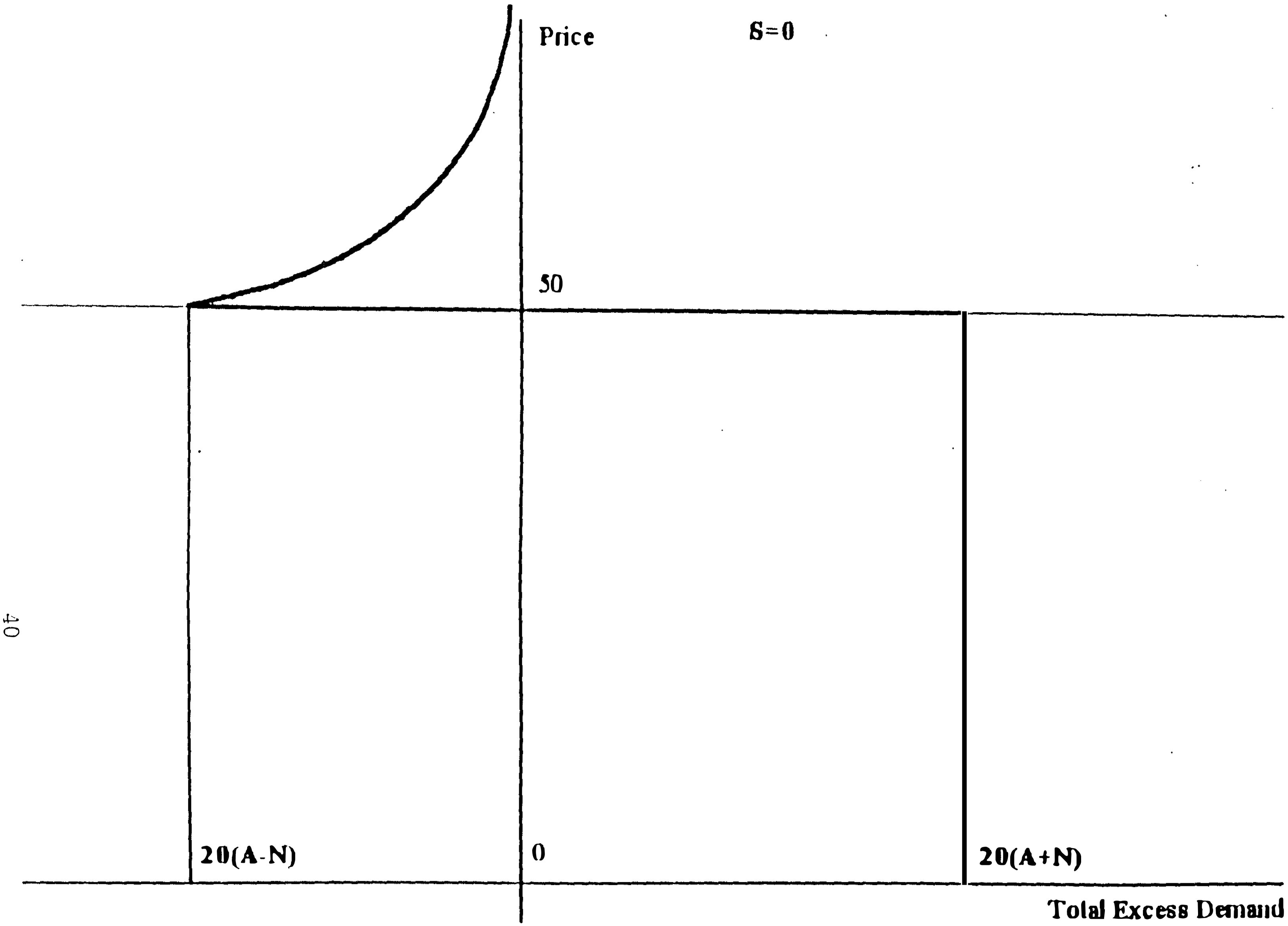
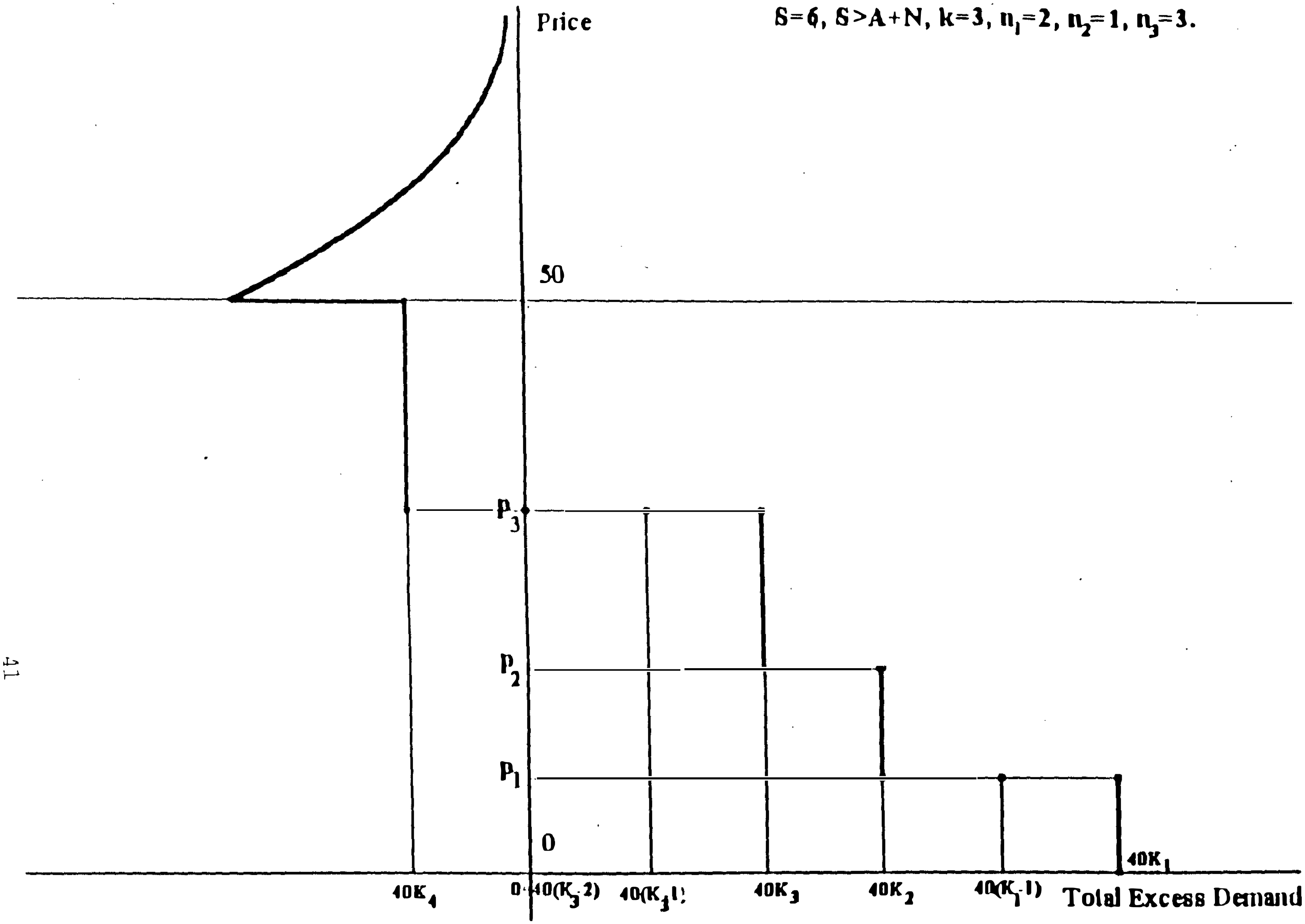


Figure 5.



$\delta=6$, $\delta>A+N$, $k=3$, $n_1=2$, $n_2=1$, $n_3=3$.
Price
50
0
p_3
p_2
p_1
$40K_4$
0
$40(K_3\text{-}2)$
$40(K_3\text{-}1)$
$40K_3$
$40K_2$
$40(K_1\text{-}1)$
$40K_1$
Total Excess Demand

Figure 6.

FIGURE 7. Experiment 0228.

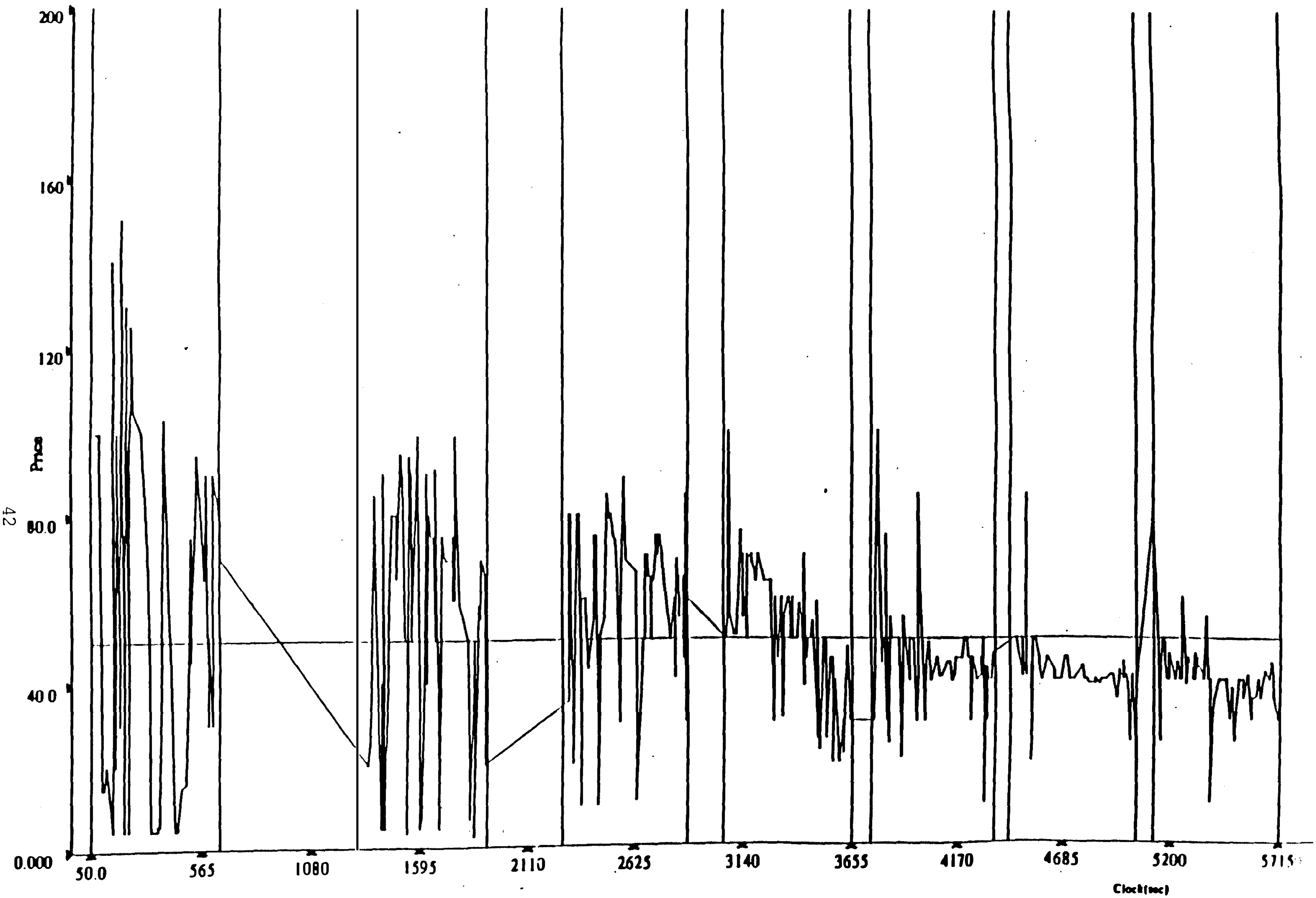


FIGURE 8. Experiment 0316.

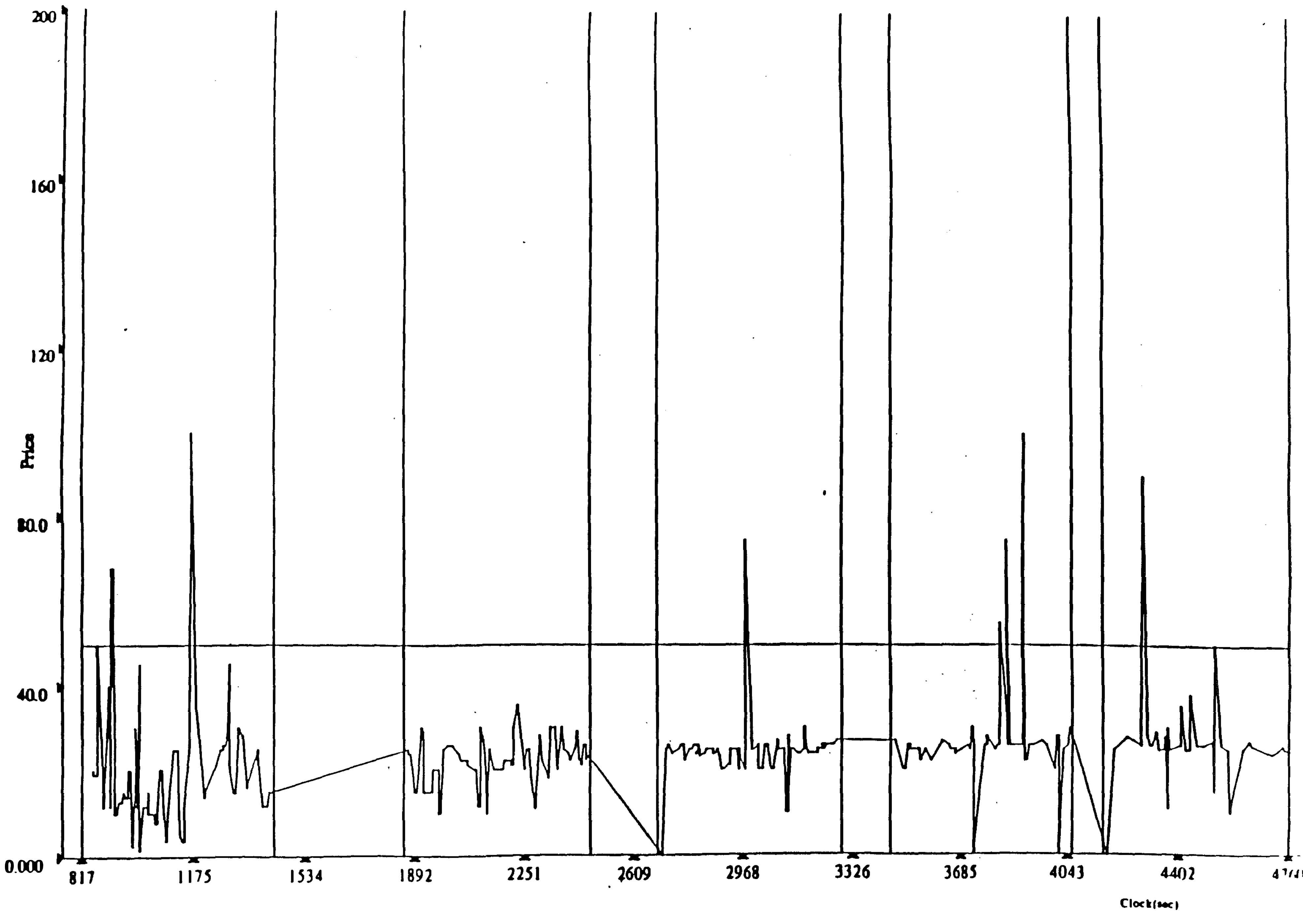


FIGURE 9. Experiment 0317.

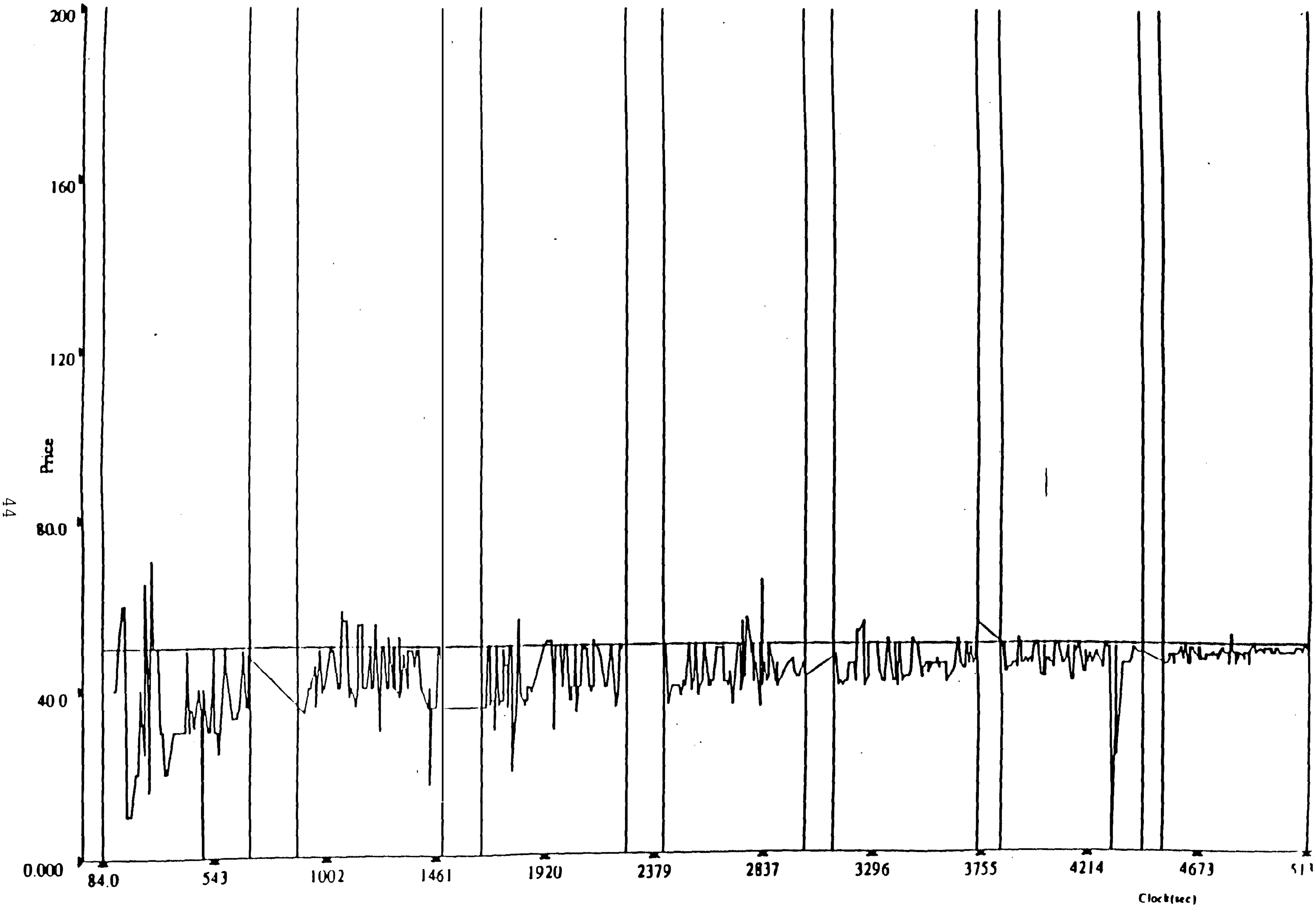


FIGURE 10. Experiment 0324.

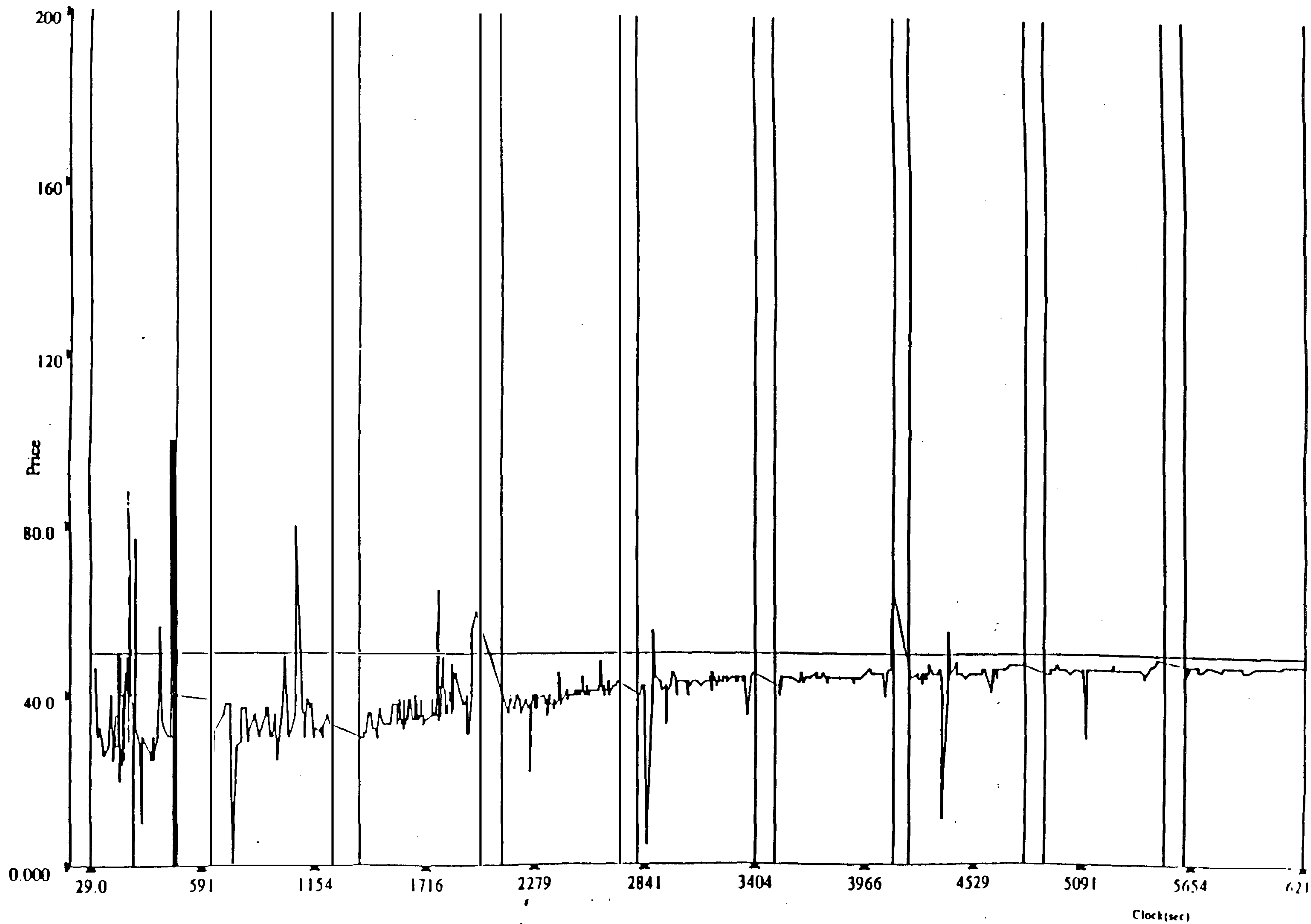


FIGURE 11. Experiment 0428.

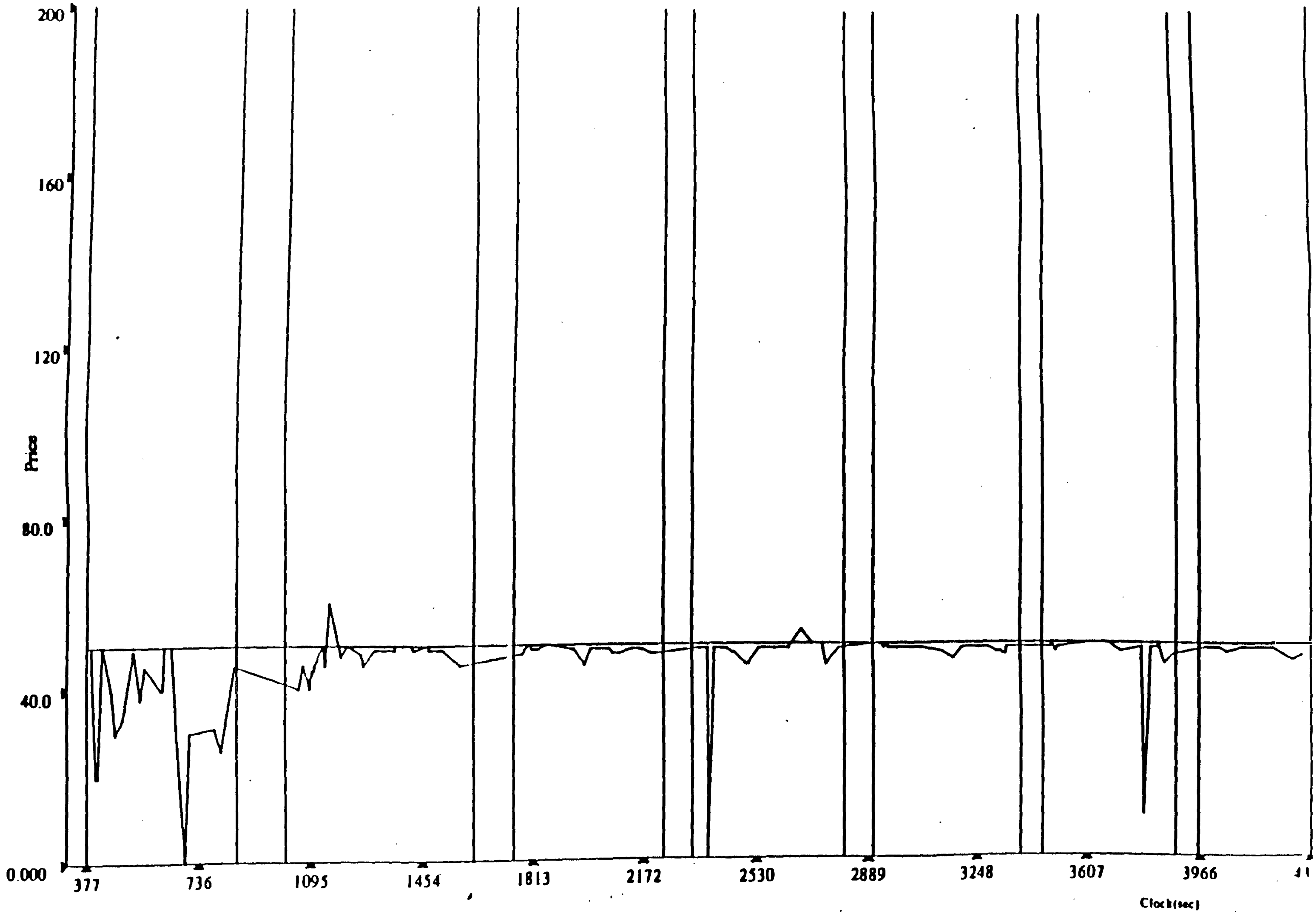


FIGURE 12. Experiment 0501.

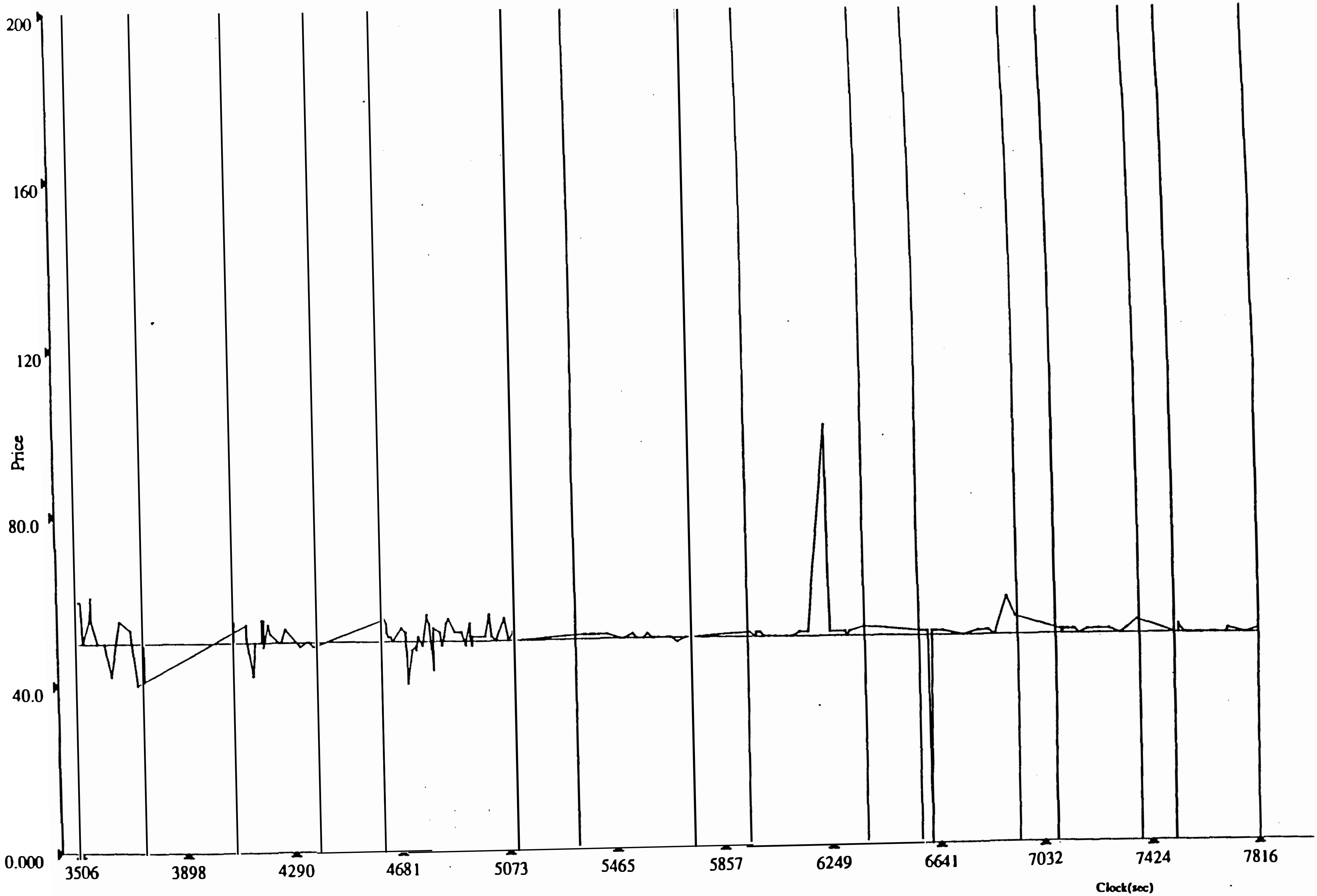


FIGURE 13. Experiment 0502.

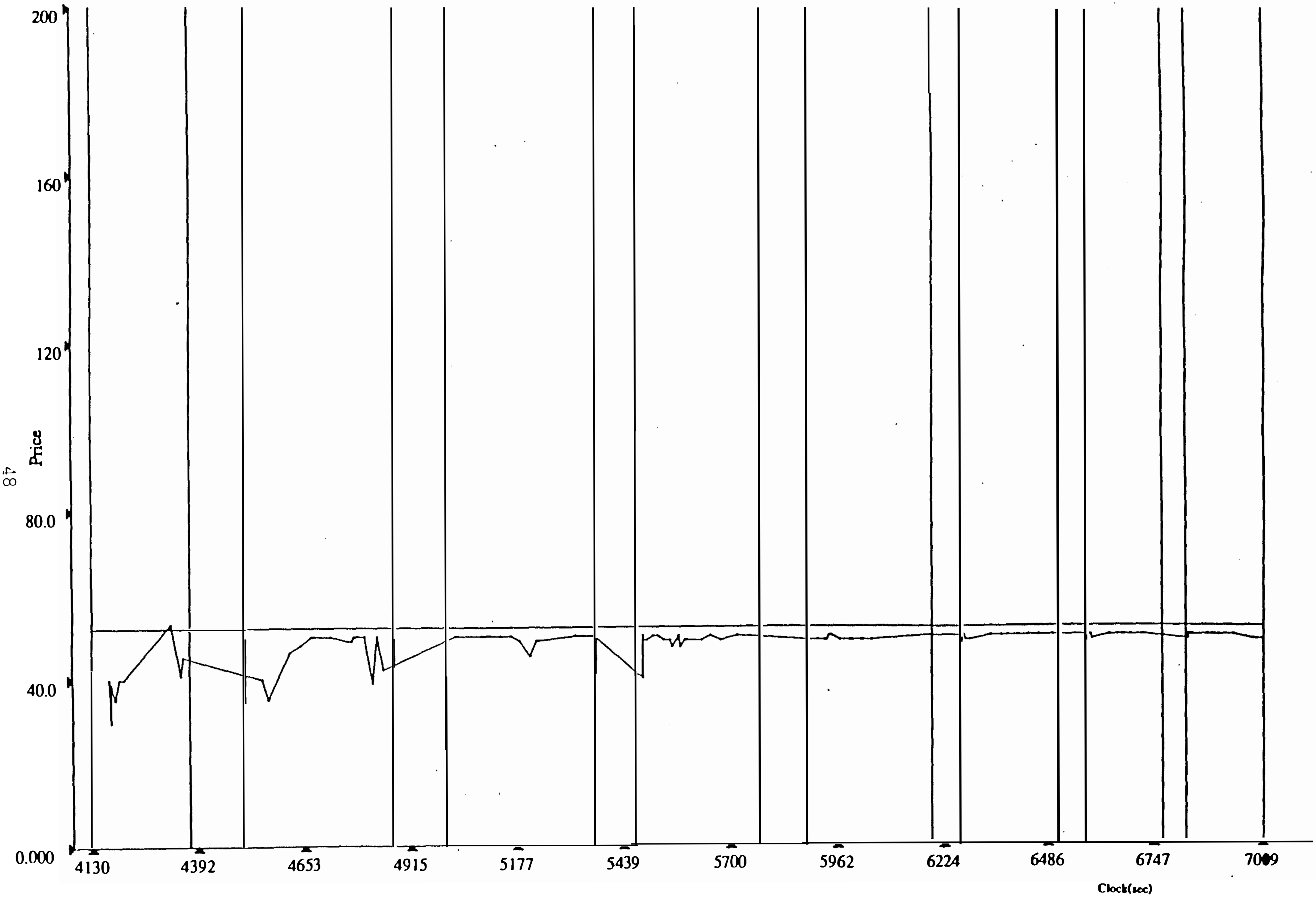


FIGURE 14.   Experiment 0505.

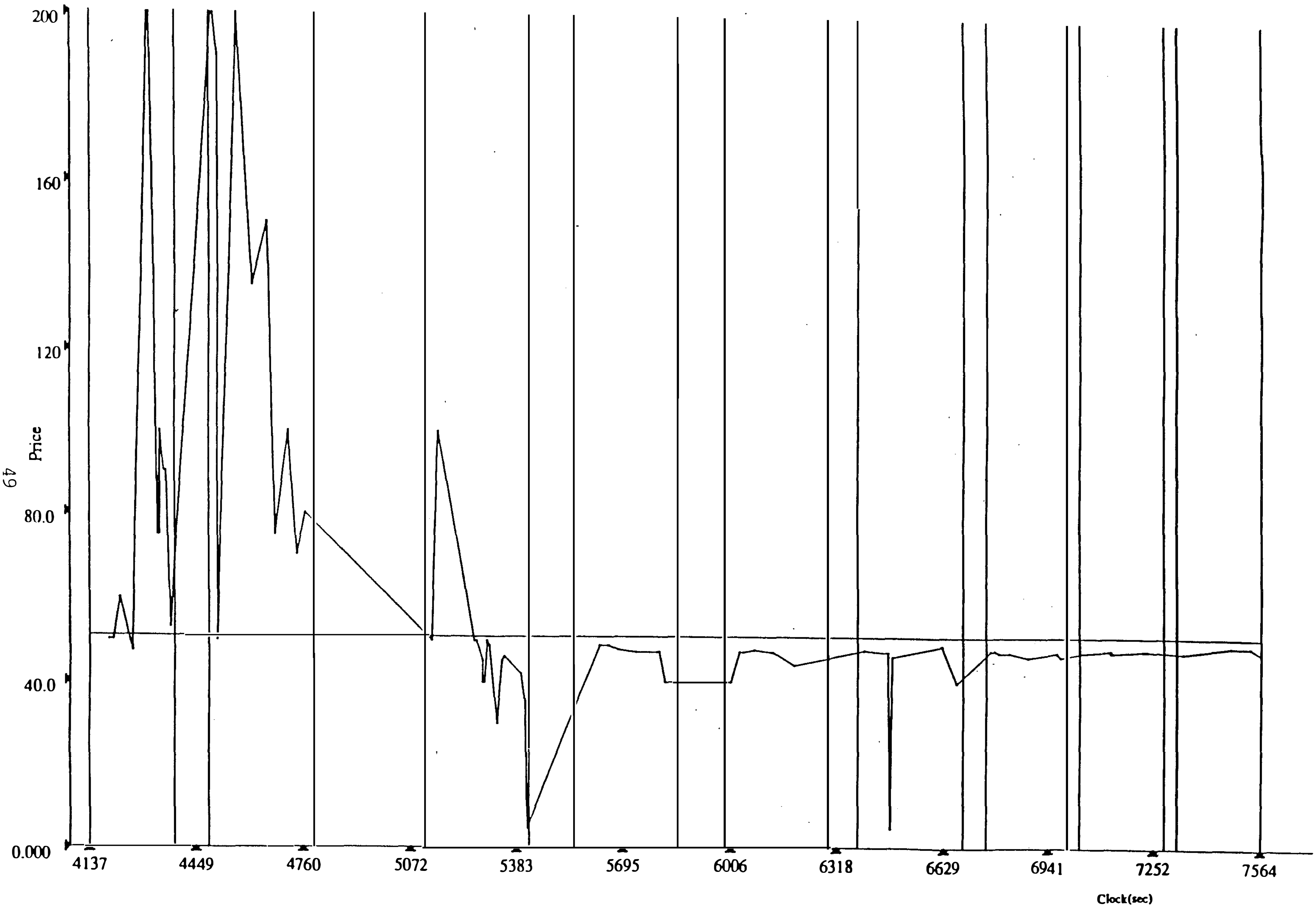


FIGURE 15. Experiment 0509.

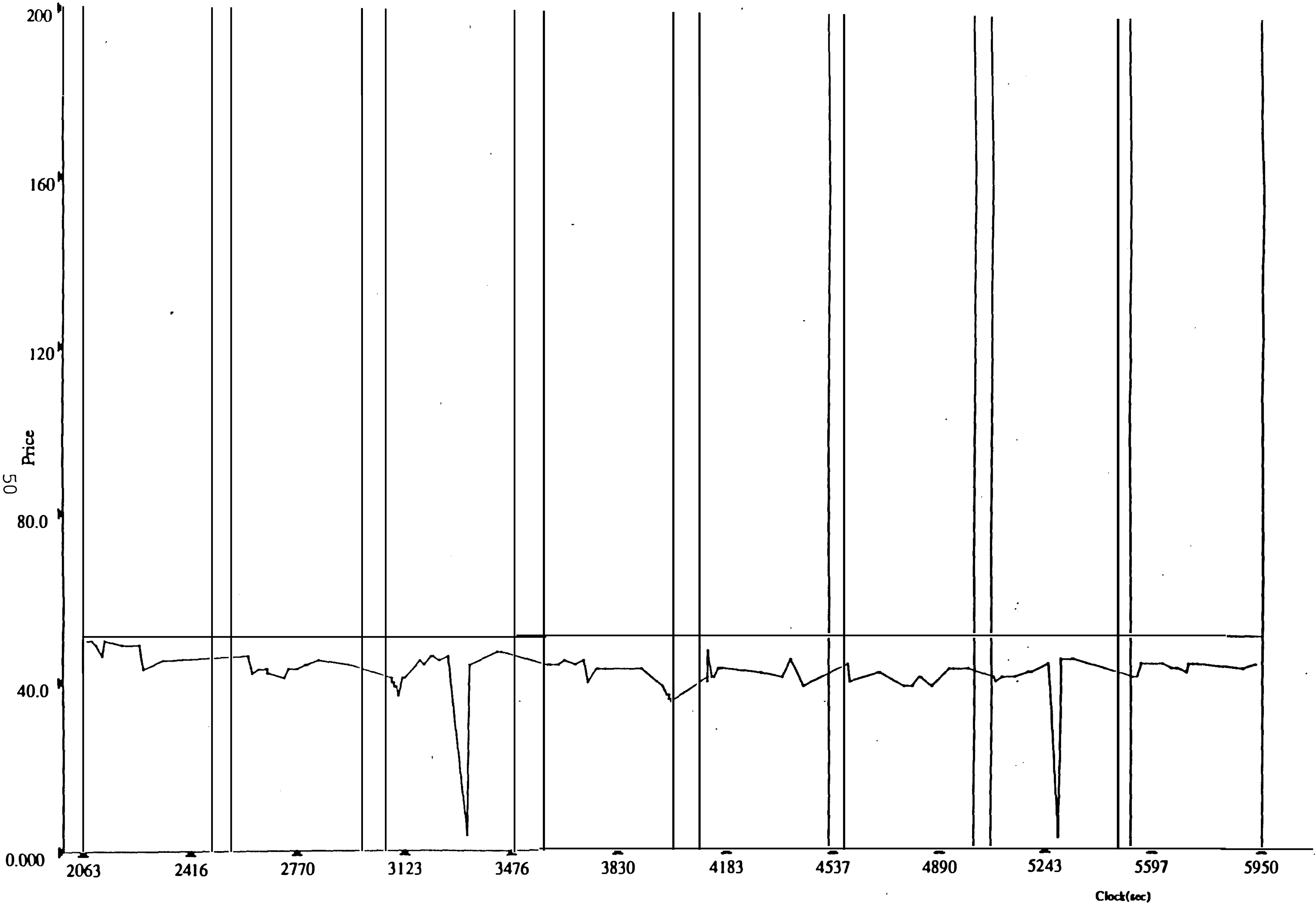


FIGURE 16. Experiment 0516.

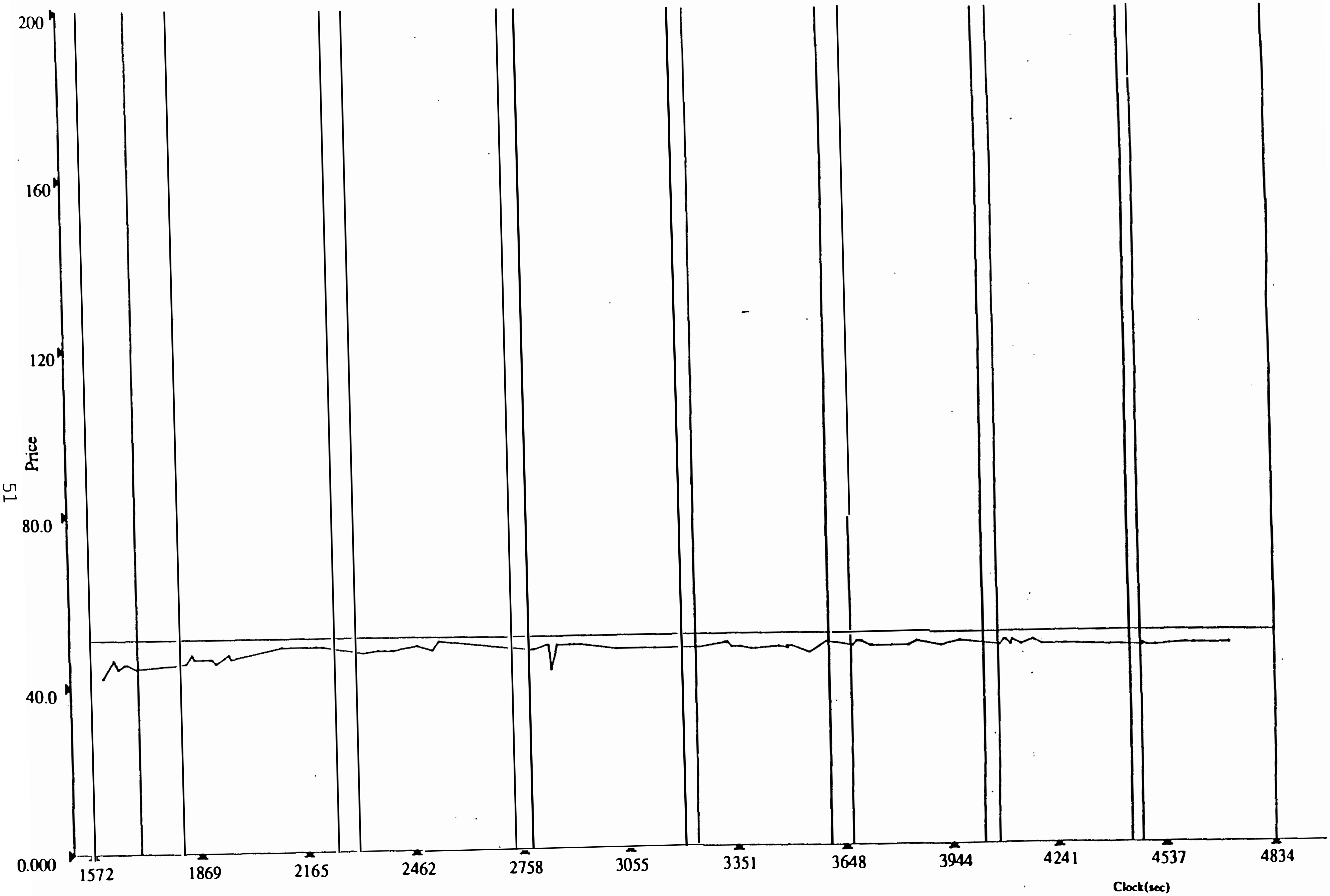


Table 1

Summary of the experiments.

Date	Location	Experienced Subjects
022894	USC	No
031694	USC	No
031794	USC	No
032494	USC	Yes[1]
042894	CALTECH	No
050195	CALTECH	No
050295	CALTECH	No
050595	CALTECH	No
050995	CALTECH	Yes[2]
051695	CALTECH (In Gains)	Yes[3]

[1] Subjects who were used in 032494 participated previously in 0316 or 0317.
[2] Subjects who were used in 050995 were among those who demonstrated risk-seeking behavior while participating in 050195, 050295 or 050595.
[3] Subjects who were used in 051695 were the same subjects who participated in 050995.

Table 2.

Competitive equilibrium predictions.

Subjects S=number of RS subjects A=number of RA subjects N=number of RN subjects	A>S+N	S>N+A	S≤N+A A≤S+N
Existence of a competitive equilibrium.	Exists.	Even number of subjects is a sufficient condition.	Exists.
Equilibrium price	>50	<50	50
Equilibrium personal net trades	≤20	=20	≤20

Table 3.

Average transaction prices.

Period#	Experiment								
	0228	0316	0317	0324	0428	0501	0502	0505	0509
0	50.35	23.29	33.01	32.82	38.19	55.21	41.15	98.18	48.85
1	51.44	21.97	43.54	34.49	47.53	51.45	44.53	49.54	42.91
2	64.12	24.05	43.18	39.33	48.17	51.85	49.41	48.81	41.98
3	56.14	26.34	44.21	39.48	48.37	50.57	48.18	46.90	43.35
4	43.33	24.17	44.83	41.27	49.15	51.20	49.20	45.70	40.77
5	42.75		45.12	43.69	48.41	49.65	49.63	44.24	41.58
6	39.61		48.36	44.88	49.04	50.67	49.84	46.92	41.51
7				46.03		50.42	49.17	47.57	42.47
8				47.37				47.18	

Practice Periods

Table 4.

Ordinary least square estimation of the convergence process.

Equation: $\mathbf{P_{IT}=B_{11}\,D_1(1/T) + \ldots + B_{1K}D_K\,(1/T) + B_2\,((T\text{-}1)/T) + u}$

I - index of the experiment, **T** - period number.

$\mathbf{P_{IT}}$ - average transaction price in period **T** of experiment **I**.

$\mathbf{D_J}$ **= 1** if i=j, **0** otherwise.

u - $N(0,s^2)$

Dependent variable- $\mathbf{P_{IT}}$

Experiment	Independent variable	Estimated Coefficient	Standard Error	t-Statistics
022894	B_{11}	50.32	2.86	17.58
031694	B_{12}	21.07	3.03	6.95
031794	B_{13}	44.35	2.86	15.50
032494	B_{14}	39.02	2.82	13.82
042894	B_{15}	49.57	2.87	17.32
050195	B_{16}	54.74	2.81	19.43
050295	B_{17}	48.33	2.81	17.16
050595	B_{18}	49.47	2.84	17.57
050995	B_{19}	39.68	2.77	14.08
	B_2	46.11	0.84	54.28

Number of observations - 49

R-squared - 0.71

Standard Error of the Regression - 3.38

Durbin-Watson Statistics - 1.78

Mean of dependent variable - 45.66

Table 5.

Standard deviations of transaction prices.

Period#	Experiment								
	0228	0316	0317	0324	0428	0501	0502	0505	0509
0	48.35	15.94	19.15	18.29	14.32	10.05	17.11	59.43	3.51
1	26.63	5.61	7.74	6.77	4.21	6.31	8.16	4.81	3.38
2	15.66	7.48	7.09	29.19	1.21	4.28	2.34	6.90	7.53
3	15.82	10.85	4.75	9.44	5.64	1.01	3.38	3.43	10.29
4	11.39	10.30	3.48	9.46	.73	.77	5.14	1.59	2.04
5	9.23		3.81	2.36	5.23	1.25	1.10	.83	2.28
6	9.46		1.31	3.92	1.05	.93	1.23	1.27	1.19
7				1.73		.64	.46	.94	1.36
8				.72				.73	

Practice Periods

TABLE 6.

Numbers of individuals with various levels of purchases and sales: average of last two periods, all experiments.

All Experiments Combined							
Final Holdings	0-0.4	0.5-4	5-8	9-12	13-16	17-20	Total Numbers
BUYERS	4	2	5	7	8	14	40
SELLERS		6	4	5	7	16	38

Table 7.

Total Net Trade Volumes.

Period#	Experiment								
	0228	0316	0317	0324	0428	0501	0502	0505	0509
0	34	66	81	54	60	54	38	28	42
1	48	46	62	60	52	67	42	23	87
2	67	52	67	58	37	101	55	48	95
3	38	32	64	55	54	54	71	23	80
4	54	34	62	55	55	62	70	50	90
5	26		60	48	60	67	53	43	88
6	42		56	51	55	76	60	40	93
7				52		78	73	40	83
8				50				40	
Competitive Equilibrium Predictions	100	100	100	100	80	100	80	60	100

Practice Periods

TABLE 8.

Comparison of the net changes of final holdings (average of the last two periods) and classification results for the subjects who participated in two experiments

Subject #	Inexperienced			Experienced		
	Experiment	Net changes of final holdings of inventory	Classification	Experiment	Net changes of final holdings of inventory	Classification
1	0316	6.5	"?"	0324	8.5	"?"
2	0316	0.5	"?"	0324	0	"?"
3	0316	10.5	RA	0324	12	RA
4	0316	-5	"?"	0324	-19	RS
5	0316	-3.5	"?"	0324	9.5	"?"
6	0316	-3	"?"	0324	-15	RS
7	0316	-1	"?"	0324	0	"?"
8	0317	-13.5	RS	0324	-17	RS
9	0317	-3	"?"	0324	11	RA
10	0317	0	"?"	0324	10	RA
11	0501	-13.5	RS	0509	20	RA
12	0501	-12	RS	0509	31.5	RA
13	0501	-12.5	RS	0509	-20	RS
14	0501	-14	RS	0509	-20	RS
15	0502	-17	RS	0509	20	RA
16	0502	-20	RS	0509	20	RA
17	0502	-19.5	RS	0509	-20	RS
18	0502	20	RA	0509	19.5	RA
19	0505	-20	RS	0509	-12.5	RS
20	0505	-17.5	RS	0509	-18	RS

Table 9.
Classification of the subjects according to their behavior.

Experiment	RA*	RS**	?
0228	3	3	4
0316	2	1	7
0317	3	3	4
0324	3	3	4
0428	2	2	4
0501	4	4	2
0502	3	3	2
0505	2	2	2
0509	5	5	0
Total	27	26	29

* These measures are upper bounds.

** These measures are lower bounds.

Table 10.

Relationship between answers to the questionnaires and experimental behavior

Type I classification.
More than 2 out of 5 answers of a particular type.

	Risk-Seeking in the Questionnaires	Risk-Averse in the Questionnaires
Risk-Seeking in the Experiment	16	2
Risk-Averse in the Experiment	10	10
"?" in the Experiment	28	7

Type II classification.
Based on the answer to the choice of loosing $20 for sure or $40 with p=1/2

	Risk-Seeking in the Questionnaires	Risk-Averse in the Questionnaires
Risk-Seeking in the Experiment	17	2
Risk-Averse in the Experiment	11	8
"?" in the Experiment	21	14